APPENDIX E

HYPOTHETICAL CASE STUDIES

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CONTENTS

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APPENDIX E. HYPOTHETICAL CASE STUDIES

I. INTRODUCTION

The two hypothetical case studies described in this Appendix illustrate the basic components of an RIA and present a format for displaying the major categories of benefits, costs, and economic impacts that typically result from major environmental regulation analyses. The case studies use hypothetical data; hence, the numbers presented do not necessarily indicate the magnitude of benefits, costs, or impacts likely resulting from any particular regulatory action. It is the analytical techniques and presentation of data for RIA's that are the focus of this appendix.

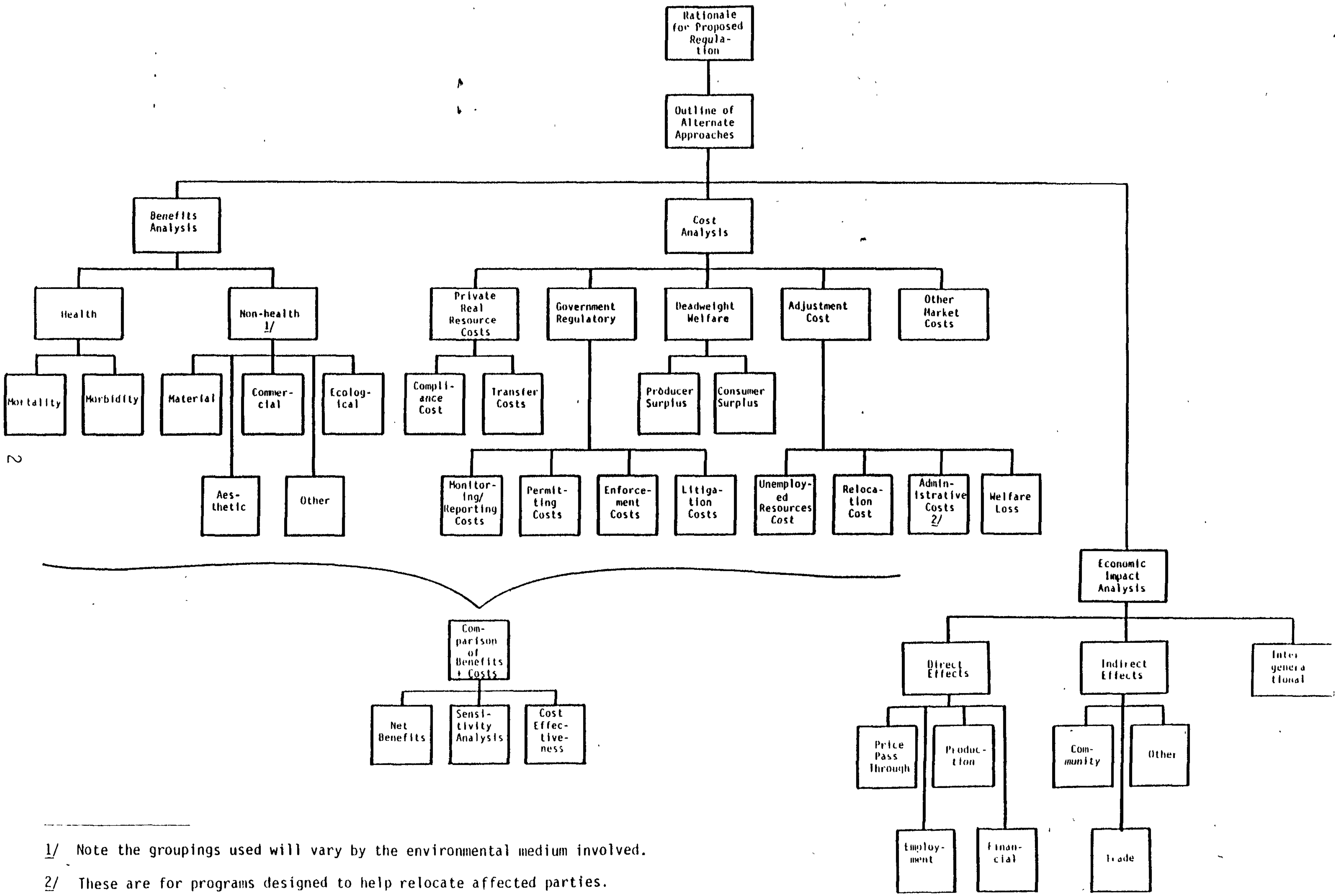
It is worth noting that, in developing the case studies, a. good deal of expository material has been included in the case studies themselves that would not be necessary in an RIA. In some instances, this exposition adds to the guidance contained in previous appendices, and in some instances, it is (for convenience) duplicative.

The major components of an RIA, as discussed in the preceding appendices, are depicted in Figure 1. This figure shows the three basic analyses that must be prepared in support of an RIA: Benefits Analysis, Cost Analysis, and Economic Impact Analysis.

The complexity of an RIA will increase with the number of regulatory alternatives being assessed. Alternatives involving only changes in stringency levels can be assessed more readily than regulatory alternatives which differ in their general approach, e.g., effluent guidelines vs. marketable pollutant permits. In the two case studies presented, only a single regulatory alternative is defined; however, a comprehensive RIA would require similar summary results for each alternative (though the level of detail in the analyses of the alternatives would not need to be as refined, because it should in most cases be possible to identify the best alternative reasonably early).

To determine which regulatory alternative will be chosen, the results from all three supporting analyses would be utilized. The benefits and cost analyses measure the efficiency of each alternative; the economic impact analysis indicates the equity of each alternative by showing the extent to which specific regions, populations, or industry groups will be affected either adversely or positively. Both aspects of proposed regulatory alternatives need to be considered because a certain alternative may have a high level of efficiency and at the same time result in unacceptable adverse impacts on affected parties. Implementation of such an alternative may require mitigating measures.

Figure 1. Components of a Regulatory Impact Analysis



1/ Note the groupings used will vary by the environmental medium involved.

2/ These are for programs designed to help relocate affected parties.

In this Appendix, two case studies are presented. The first case study is of an hypothetical, proposed air pollution control regulation in which the ambient air quality standard is to be changed for a given pollutant. The second case study is of an hypothetical, proposed water effluent guideline regulation.

The following elements of an RIA are summarized for each case study.

- Net Benefits Evaluation and Impact Summary
- Background, including Characteristics of the Regulated Parties
- Social Benefits
- Social Costs
- Economic Impacts
- Net Benefits Timestreams and Sensitivity Analysis
- Cost-Effectiveness

II. AIR POLLUTION CONTROL REGULATION CASE STUDY

This case study illustrates the method of conducting and the means of reporting on the economic analysis portion of a Regulatory Impact Analysis (RIA) for a hypothetical stationary source air pollution control regulation which proposes to increase the stringency of an ambient air quality standard for a specific, though unspecified pollutant--Pollutant X.

The case study assumes that a discussion of the need for the regulatory action and the relevant statutory authority have been presented elsewhere (an abbreviated "Background" section is contained in II. B. below). Moreover, both the format and the depth of analysis of the various elements of the RIA are only intended to be illustrative: The Agency is not at this point committed to any specific format, and the depth of analysis must clearly be tailored to the problem at hand.

Although based on data established in relevant literature and previous benefit-cost studies and regulatory impact analyses, the information presented should not be viewed as reflective of a known pollutant or of a proposed regulation; rather, all data are but illustrative. To reduce the complexity of this first hypothetical case study, Pollutant X is assumed to be regionally specific; however, to illustrate the aggregation problems often encountered in determining national level benefits and costs, that region is divided into three areas. "Adding up" the benefits and costs of these three areas to arrive at regional totals is analogous to adding up regional-level benefits and costs to estimate national totals. These areas reflect the regionally differing major concerns germane to preparing an RIA (e.g., pollutant levels, population, and industry characterizations).

This case study is organized into seven major sections. The first, the Net Benefits Evaluation and Impact Summary, summarizes the findings of this case study and outlines the types of analyses necessary to complete an RIA. The second section, Background, outlines that information pertinent to the region examined in this case study. The remaining five sections--Social Benefits, Social Costs, Economic Impacts, Net Benefits Timestreams and Sensitivity Analysis, and Cost-Effectiveness--present the analyses used in this case study and illustrate the types of procedures which may be necessary to completing an RIA.

A. Net Benefits Evaluation and Impact Summary

Tables 1 through 6 summarize the information required for an RIA Executive Summary. Though results are provided for only one of the regulatory alternatives, such development would be needed for each alternative examined that is in the least-cost set of alternatives as determined from appropriate cost-effectiveness‘analysis (see Section G). For the alternative shown, Tables 1-6 present information for each of the three major analyses--benefits, costs, and economic impacts--and show the alternative's quantitative and nonquantitative effects. Monetized impacts cover a twenty-year planning period (beginning in 1982) and all values are expressed in 1982 dollars.

Table 1, Part A, shows the present values for the quantified net social benefits of the proposed Pollutant X air pollution control regulation using alternate discount rates. For example, the present value of the total social benefits minus the total social costs over the 20-year period of analysis is $84 million at the 10 percent discount rate. For lower discount rates, e-.g., 6 and 8 percent, the present values of the net social benefits are higher, and for higher discount rates, e.g., 12 percent, the present values are lower. (The present value of the net social benefits would be zero at a discount rate of approximately 30 percent for this case study.) Sensitivity analysis results from varying benefits and cost values are shown in Section F.

Table 1, Part B, summarizes the unquantified benefits and costs associated with the proposed regulation. It appears that the unquantified benefits will exceed the unquantified costs based upon qualitative judgments. Furthermore, an estimated 1,269 premature deaths (a quantifiable but nonmonetizable impact) will be avoided with the regulation--a further major benefit excluded from the present value calculations. Had costs exceeded benefits in the present value calculations, then the excess cost per death avoided would be a measure that would be reported.

Annual, undiscounted benefits and costs are presented in Table 2 to show benefit accrual and cost expenditures over the 20-year planning period. Net social benefits (the differences between benefits and costs) were calculated on an annual basis and, as shown, they are negative from 1983 through 1985. Beyond this period, net social benefits are positive and increase to $33.7 million in the 20th year.

Table 3 summarizes the social benefits of the proposed regulation by benefit type. The monetizable benefits are shown by year over the planning period, including ranges in the benefit values to reflect uncertainties regarding available data and the implementable analytic procedures for estimating specific types of benefits. The four major types of benefits shown include health, visibility, soiling, and ecological benefits. The soiling and visibility benefits are the highest, with the former ranging from $7.2 million in the second year of the planning period to $26.8 million in the last. The latter ranges from $7.2 million in the second year to $37.6 million in the last. Ecological and health benefits are much lower, reaching highs of $3.7 and $15.4 million, respectively, in the twentieth year.

Table 3 also presents the major quantifiable/non-monetizable health benefits (Part B) and a listing of nonquantifiable benefits (Part C). These latter benefits are particularly important when the present value of

Table 1. Net social benefits from the proposed Pollutant X air pollution, control regulation using alternate discount rates

Part A. Quantified Benefits and Costs

	Present Value 1/ Using Alternate Discount Rates			
	6%	8%	10%	12%
	----------------millions of dollars-------------			
Social Benefits	644.8	532.2	444.7	375.9
Social Costs	499.3	421.9	361.0	312.5
Net Social Benefits 2/	145.5	110.3	83.7	63.4

Part B. Unquantified Benefits and Costs

The unquantified benefits include:

- reduced pain and suffering
- reduced threat of illness and death,
- increased safety for air and surface transport, and
- reduced maintenance and replacement costs for ornamental plants and structures (e.g., statues)

When compared to minimal adjustment costs (which were the only unquantified costs for this regulatory alternative), these benefits likely exceed costs for unquantified benefits and costs as well.

1/ Present values of costs and benefits over a 20-year planning period in 1982 constant dollars.

2/ In addition to the net benefits shown in this table, 1,269 premature deaths were avoided during the planning period. (According to EPA guidance, these should be compared to costs which are in excess of dollar benefits; however, this regulation's costs do not exceed its dollar benefits. Thus, the cost per life saved is zero and the benefits from deaths avoided are in addition to the quantified benefits).

Table 2. Undiscounted total social benefits, total social costs and net social benefits for the proposed Pollutant X air pollution control regulation by year

	Year	Total social benefits 1/		Total social costs 2/		Net social benefits 3/	
		Estimate	Range	Estimate	Range	Estimate	Range
		millions of dollars					
1	1982	0	0			0	
2	1983	19.6	14.3-24.3	40.8	36.7-44.8	(21.2) 4/	(22.4)-(20.46)
3	1984	37.5	27.7-46.0	54.8	49.4-60.2	(17.3)	(21.7)-(14.2)
4	1985	57.2	42.8-71.1	67.7	60.9-74.4	(10.5)	(18.1)-(3.3)
5	1986	59.3	44.2-73.8	41.7	37.5-45.9	17.6	6.7-27.9
.							
10	1991	66.3	49.3-82.7	43.6	39.2-47.8	22.7	10.1-34.9
.							
.							
.							
15	1996	74.6	55.5-93.3	48.7	43.8-53.3	25.9	11.7-40.0
.							
.							
.							
21	2001	83.6	61.3-104.6	51.1	46.0-56.0	32.5	15.3-48.6

1/ In 1982 constant dollars (using a forecast of the GNP Implicit Price Deflator).

2/ In 1982 constant dollars.

3/ Total social benefits minus total social costs.

4/ Numbers in parenthesis are negative.

Table 3. Summary of total social benefits for the proposed Pollutant X air pollution control regulation by year

Part A. Quantifiable/Monetizable Benefits 1/

		Benefit types									
		Health		Visibility		Soiling		Ecological		Total benefits 2/	
	Year	Estimate	Range	Estimate	Range	Estimate	Range	Estimate	Range	Estimate	Range
		millions of dollars									
1	1982	0	0	0	0	0	0	0	0	0	0
2	1983	3.0	1.8- 4.2	7.2	5.7- 8.5	7.2	5.5-8.9	2.3	1.7-2.6	19.6	20.9- 24.2
3	1984	6.2	3.7- 8.9	13.6	10.8-16.2	15.1	11.5-18.7	2.5	1.9-2.9	37.4	27.9- 46.7
4	1985	9.3	5.4-13.1	22.6	17.9-26.9	22.4	17.1-27.7	2.9	2.2-3.4	57.2	42.6- 71.1
5	1986	9.7	5.7-13.6	22.8	18.2-27.2	23.8	18.2-29.5	3.0	2.3-3.4	59.3	44.4- 73.7
. . .											
10	1991	11.4	6.7-16.1	24.1	19.2-28.7	27.6	21.1-34.2	3.1	2.4-3.6	66.3	49.4- 82.6
. . .											
15	1996	13.3	7.8-18.8	25.4	20.2-30.3	32.4	24.8-40.1	3.4	2.6-3.9	75.6	55.4- 93.1
. . .											
20	2001	15.4	9.1-21.8	26.8	21.3-32.0	37.6	28.7-46.3	3.7	2.8-4.3	83.5	61.9-104.4

Part B. Quantifiable/Non-monetizable Benefits

During the twenty-year planning period, an estimated 1,269 deaths will be avoided due to the proposed regulatory alternative. On a yearly basis, the total number of deaths avoided ranged from 17 to 90 (excluding the first year when no lives were saved). Since benefits exceed costs, the cost per life saved is zero, and there is no need to attempt valuation of life saved in this instance.

Part C. Non-quantifiable benefits

1. Reduced pain and suffering from illness and death
2. Reduced threat of illness and death
   Decreased risk from air and surface travel
4. Decreased maintenance and replacement costs for ornamental plants and structures (i.e., statues)

1/ In 1982 constant dollars (using the GNP Implicit Price Deflator) to allow direct comparison with costs. Additionally, the beginning of the examined planning period is 1982 and present values were calculated for that year.

2/ The sum of the individual costs may not equal the total costs due to rounding errors.

net social benefits is relatively small or negative. The quantifiable/ nonmonetizable benefits include the avoidance of 1,269 deaths which on an annual basis ranged from 17 to 90. Non-quantifiable benefits include reduced pain and suffering, reduced threat of illness and death, increased travel safety, and decreased maintenance and replacement costs for ornamental plants and structures (e.g., statues, buildings).

Table 4 summarizes total social costs by type of cost, including private sector real resource costs, deadweight welfare loss, government regulatory costs, and adjustment costs (nil in this case study). Private sector real resource costs are the highest and range from a low (excluding the first year when costs are zero) of $40.3 million in the second year to a high of $50.8 million in the 20th year. Government costs are next highest with a high of $0.7 million in the fourth year and a low (excluding year one) of $0.1 million in the 20th year. Deadweight welfare costs remain at approximately $1 million per year. Adjustment costs are minimal and were, thus, left unquantified for this case study.

The preceding benefits and costs reflect the major efficiency-related impacts of the proposed regulation. Equity-related impacts are also of concern in an RIA. Table 5 summarizes the major economic impacts that are projected to result from the regulation with the implicit focus on equity issues. Six categories of effects included in the table are the following: financial, price, production, employment, community, and other effects. In some cases, the economic impacts associated with a proposed regulation may result in modifying implementation strategies or developing transitional programs to compensate for major inequities caused by regulations.

The table shows that Industry A has the highest potential reduction in its plants' returns on sales at 2.7 percent and Industry C has the lowest at 0.4 percent. Reflecting this reduction in sales return, price increases needed to maintain profitability are the highest for Industry A at 3.8 percent, 3.2 percent, and 3.0 percent for small, medium and large plants, respectively. Industry C requires only an 0.8 percent price increase to maintain profitability. Projected production decreases are also the highest for Industry A (1.16 percent) and the lowest for Industry C (0 percent). Though no plant closures are foreseen, Industry A's production decrease will likely result in some short-term unemployment; however, this should have minimal community effects because of long-term industry growth.

Table 6 summarizes this study's cost-effectiveness (C/E) analysis results, which are presented in the concluding section of this case study report. Once a level of control is specified, C/E analysis is an analytical technique for comparing regulatory alternatives. Its use in the early stages of an RIA will aid in reducing the number of alternatives which will require further analysis in a benefit-cost framework. As shown in Part A, six regulatory alternatives, A to F, are depicted with their corresponding annualized costs and emissions abated (tons of Pollutant X abated). Based on C/E analysis only, Alternative D is clearly preferable to Alternatives A, B and C because D is the least costly and most effective alternative. Alternatives E and F are also least-cost alternatives, but with lower and higher abatement, respectively, as depicted in Table 6, Part B.

Table 4. Summary of undiscounted total social costs for the proposed Pollutant X air regulation (1982 dollars)

Part A. Quantifiable/Monetizable Benefits

	Year	Private sector real resource		Deadweight welfare		Government		Total costs 1/	
		Estimate	Range	Estimate	Range	Estimate	Range	Estimate	Range
		---millions of dollars---							
1	1982	0	0	0	0		0		
2	1983	40.3	36.3-44.3	0.1	<.1 2/	0.4	<.1	40.8	36.7-44.8
3	1984	54.2	48.8-55.5		<.1	0.6	0.5-0.6	54.8	49.4-60.2
4	1985	66.9	60.2-73.4	0.1	0.1-0.2	0.7	0.6-0.8	67.7	60.9-74.4
5	1986	41.0	36.9-45.0	0.1	0.1-0.2	0.5	0.5-0.6	41.7	37.5-45.9
.									
.									
10	1991	43.1	38.8-47.3	0.1	0.1-0.2	0.3	0.3-0.4	43.6	39.2-47.8
.									
15	1996	48.3	43.5-52.9	0.1	0.1-0.2	0.2	<.1	48.7	43.8-53.3
.									
20	2001	50.8	45.7-55.6	0.1	0.1-0.2	0.1	0.1-0.2	51.1	46.0-56.0

Part B. Non-quantifiable Costs

1. Minimal level of unemployed resources, re-employed in long-run
2. Displacement costs over the period of temporary unemployment are negligible
3. Administrative costs for transfer payment program over the periods of unemployment are minimal.

1/ The sum of the individual costs may not equal the total costs due to rounding errors.
2/ Range is less than .1 above or below the estimate.

Table 5. Summary of economic impacts from the proposed pollution controls in Industries A, B and

A. Financial Effects

Industry A:

- Average 2.7 percent reduction in return on sales for firms before marker adjustments.
- All firms remain viable with positive NPV's in 20th year.

Industry B:

-
- Small plants are marginally viable with pollution controls before market adjustments that increase prices by 0.9 percent.

Industry C:

- A 0.4 percent reduction in return on sales for firms using either Process 1 or Process 2.
- Annual cash flow and net present value effects of pollution controls are relatively minor over the 20-year period of analysis.

B. Price Effects

Industry A:

- Required price increases to maintain profitability are 3.8 percent, 3.2 percent, and 3.0 percent for small, medium and large plants, respectively
- An industry-level price increase of 3.3 percent is projected following market equilibrium adjustments.
- A sensitivity analysis of pollution control costs shows that Industry A's model plants are affected measurably by relatively small changes (±10 percent) in the estimated pollution control investment and annual operating costs.

Industry B:

- Required price increases of 2.5 percent, 1.8 percent, and 1.7 percent are estimated for the small, medium and large model plants.
- Because of both supply and demand elasticity effects, the expected market price adjustment after pollution controls is a 0.9 percent increase (and a production effect as summarized below).

Industry C:

- Price increases of only 0.8 percent are required by either type of model plant--Process 1 or Process 2.
- With a perfectly inelastic demand assumed for Industry C, the projected price increase after market adjustments is also 0.8 percent.

c. Production Effects

industry A:

- A 1.6 percent reduction in industry output (relative to baseline production) is forecast with pollution controls.
- Reduced levels of production are forecast throughout the 20-year period of analysis.

Industry B:

- A 0.9 percent reduction in output is expected from the baseline levels with pollution controls.
- Both supply and demand relationships contribute to this industry-level effect.

industry C:

- No reduction in the production level, relative to the baseline level, is projected because a perfectly inelastic demand function is considered applicable to this industry.

3. Employment Effects

- No plant closures are forecast and, thus, no employment losses are expected.
- The most significant reduction in output from the baseline is 1.6 percent in Industry A. This reduction is not expected to result in short-term employment lay-offs since a 1 percent growth in demand per year was also projected.
- Positive employment effects are expected for two reasons: (1) short-term construction employment to install pollution controls -- totalling 486 work years for Industries A, B and C; and (2) long-term industry employment to operate and maintain the pollution controls -- 150 in Industry A, 125 in Industry B, and 32 in Industry C.
- No significant secondary employment effects (in raw material suppling industries or in substitute product industries are forecast. Also, the pollution control equipment industry is expected to supply the required equipment from existing sources under normal operating conditions.

E. Community Effects

- Negligible community effects are expected because neither plant closures nor major production effects are forecast.

F. Other Effects

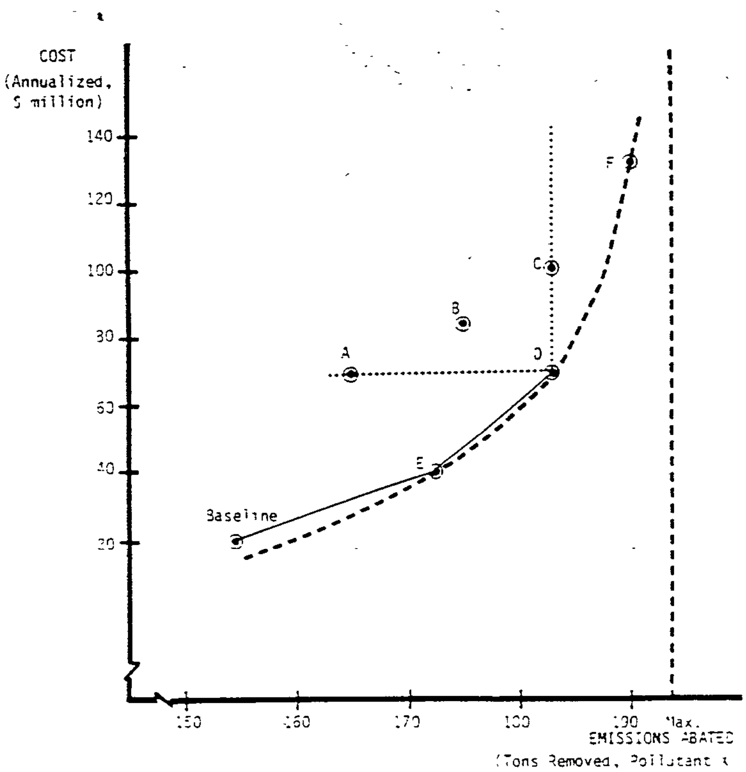
- International trade effects will be minor.
- Energy consequences of the regulation are expected to be negligible.
- No productivity effects will occur because the pollution controls will not alter production processes.
- Intergenerational effects are reflected via damage reductions in the benefits analysis. No other types of intergenerational effects are expected.

Table 6. Summary of Cost-effectiveness Analysis Results for the Proposed Regulatory Alternative Versus Other Alternatives, All Industries

Part A. Cost-effectiveness Values (Aggregate)

Regulatory alternative	cost 1/	Emissions Abated 2/	C/E value 3/	Comment 4/
	($million)	(1,000 tons)	($/ton)	
Baseline	20.0	154.9	129	
A	71.3	165.0	432	Inferior to D and E
B	86.0	175.0	491	Inferior to D
C	86.0	183.2	562	Inferior to D
D	71.3	183.2	389	In least-cost C/E set
E	41.0	172.5	238	In least-cost C/E set
F	134.0	190.0	,705	In least-cost C/E set

Part B. Graphic Display of C/E Analysis



1/ Annualized total cost of abatement (pollutant removal) for each specified regulatory alternative.

2/ Total tons of pollutant removed for each specified regulatory alternative.

3/ Cost divided by emissions. Note that other C/E measures should also be defined (such as the incremental cost above baseline and the incremental emissions above baseline) which will more closely represent the (theoretically preferred) marginal cost effectiveness for each alternative.

4/ An inferior alternative is neither less costly nor more effective than the indicated (or dominant) alternative(s).

Benefit-cost analyses are required for each of these alternatives to determine which level of effectiveness will provide the greatest,net social benefit. Such a comparison (using hypothetical results) is shown in Section G.

The remainder of this report reflects a benefit-cost analysis of a single regulatory alternative: Alternative D, as defined in Table 6. Similar benefit-cost analyses are applicable for all cost-effective alternatives that form the so-called least cost envelope curve as illustrated in Table 6, Part B. However, for illustrative purposes, it was only deemed necessary to summarize the benefit-cost analysis for one (the preferred) regulatory alternative.

B. Background

For this case study, it is assumed that recent scientific evidence indicates that current ambient standards for Pollutant X are not low enough to protect the health and welfare of populations exposed to this pollutant, thus necessitating further regulation of Pollutant X. Due to the uncertainties currently surrounding the effects of long-range transport of air pollutants, this issue is not addressed in this case study. Additionally, it is assumed that any health risk analysis has already been completed.

Table 7 lists the major characteristics of the hypothetical 1 region examined in this case study. The Table's data are grouped into the three geographical areas-- urban, suburban and rural. The major characteristics presented include Pollutant X levels and population growth rate and structure. (Industry composition, current size, and growth rate are discussed in Section E below.)

With existing regulations in place, the Pollutant X concentration level is assumed to be highest in the urban area (with an annual arithmetic mean of 100 ug/m^3), followed by the suburban and rural areas (at 85 ug/m^3 and 75 ug/m^3, respectively). These levels are expected to increase during the study period's twenty years (1982-2002) due to industry and population growth.

The 1982 population levels were set at 600,000, 400,000 and 50,000 for the urban, suburban and rural areas, respectively. Each is assumed to change at a fixed rate (Table 7) during the study period with both the urban and suburban areas increasing and the rural area decreasing slightly.

Table 7. Characteristics of the Regulated Hypothetical Region

Characteristics	Urban	Suburban	Affected Rural
Pollutant X:			
Annual arithmetic mean (ug/m^3)	100	85	75
Percent change during study period	20% (approx 1%/yr)	10% (approx ½%/yr)	<1%
Population:			
Number in first year	600,000	400,000	50,000
Net annual rate of change	+1%	1.2%	-.5%
Mortality rate	.9%	.9%	.9%
Age Distribution		.25	.25
0-13 years	.20		
13-65 years	.50	.60	.50
>65 years	.30	.15	.25

C. Social Benefits

Before discussing the analytic procedures proper for this case study, some comment is necessary to indicate those concerns which an analyst must address prior to instituting the analytic procedures, per se. Such concerns are significant since they will guide data collection and estimation and will help determine the accuracy of the results. These concerns include (1) determining what expected and immediate effects will result from a decrease in pollutant concentrations, (2) deciding on methods to quantify and value these effects to the extent possible, (3) determining the study "unit" and its subsets, and (4) deciding upon what would constitute a sufficiency of data to support a responsible benefit analysis-.

In the first instance--determining what impacts will result from a pollution decrease--such effects for air pollution may be divided into four major groupings: health, visibility, material damage and soiling, and ecological effects. As is shown in Table 8, these may be further divided (not all, of course, are applicable in each case). At times, study funds and other available staff-resources may be limited, and an analyst may have to limit the study only to those categories which are most likely to produce the most consequential effects.

The second step is to value (where possible) these effects. Alternative valuation methods may be applicable and may include direct cost estimation, examination of property values, hedonic wage studies, and willingness-to-pay surveys. However, in choosing the methods of valuation, care must be taken that the effect measured is clearly delineated because several of the methods measure more than one effect. For example, though the assessment of changes in property values can be used to measure visibility effects, it would doubtless reflect the benefits of other effects. as well:-the decreased risk of illness due to air pollution and the decrease in material soiling and damage (Hershaft, 1978). Knowing specifically what each technique measures is of concern since quantifiable benefits must be aggregated in the RIA, and if care is not taken, double counting can occur.

The third step is to determine the study "unit." Often the region affected by a proposed regulation will be made up of different subunits, and each of these has its own set of characteristics that influence the amount and types of benefits resulting from the proposed regulation, since benefits are inherently receptor-specific. Thus, the analyst must often divide the study region into subunits which will allow a more accurate benefit estimation. The exact nature of this subdivision is often determined by the type of data available, the kinds of benefit estimation procedures used, and the specific characteristics of the study region. The analyst must also recognize that the benefit estimates for each of these subunits must eventually be aggregated to obtain total benefits for the region; hence, the subunits must have comparable characteristics.

Table 8. Types of effects resulting benefits from a reduction in air pollution

Major Effect Categories	Types of Effects	Resulting Benefits
I. Health	a. Reduced mortality	1. Increased length of life and reduced probability of death 2. Reduced pain and suffering
	b. Reduced morbidity	1. Reduced medical expenses 2. Reduced pain and suffering 3. Reduced work loss days 4. Increased productivity 1/
II. 'Visibility	a. Reduced obstruction of view b. Increased days of clear unpolluted skies	1. Increased appreciation of home and work place 2. Increased enjoyment of recreational experience 3. Increased satisfaction from knowing the air in area is clean 4. Increased satisfaction from knowing that views will not be obscured in areas that the individual may not visit, but feels area has enough intrinsic value that it should be preserved. 5. Increased safety for air and automobile/truck travel
III. Material Damage and Soiling Effects	a. Decreased soiling b. Decreased material damage	1. Decreased cleaning costs 2. Decreased replacement costs
IV. Ecological Effects	a. Decreased damage to commercial crops b. Decreased damage to ornamentals c. Decreased damage to natural systems	1. increased revenues 2. Decreased maintenance costs 3. Increased enjoyment of recreation 4. Increased existence and preservation benefits

1/ Measured as decreased work days of decreased productivity assignable to employee lassitude."

The fourth step, then, is one that determines the study's data (primary or secondary) collection procedures. A census of all study units is ideal (aggregation, in that case, would be just a summation over all subunits); however, often insufficient time and resources prevent doing this. To help assure a more accurate estimate of mean parameters in such instances, these study units should be so stratified that they minimize study unit differences within each grouping and maximize differences among groups. Only a subset of the study units from each group are studied (selected randomly) and benefit estimates obtained which represent an "average" study unit for each grouping. These values are then multiplied by the number of study units in each grouping and summed.

As was stated previously, the hypothetical region examined in the present case study was subdivided into three study units--urban, suburban, and rural areas--to reflect the fact that the types and amounts of benefits realized in each will be somewhat different (e.g., health effects will be larger in the urban area than in the rural area). To reduce the complexity of calculations, these areas were not subdivided in this case study; however, in an actual RIA, such a procedure would be advisable (for instance, a subdivision into counties is often desirable since many types of data are often available at this level).

For the purpose of illustration, benefits from most of the categories shown in Table 8 will be examined in this case study. Often sufficient data will not be available to address all categories or some categories will not be applicable to a particular regulation). In the first four of the five following sections of this illustrative case study, these categories are presented by major benefit grouping. The fifth section deals with the aggregation of the benefit groupings.

1. Health Effects

This section addresses the health benefits resulting from a reduction in Pollutant X. Only the most stringent regulatory option (an assumed 65 ug/m^3 annual arithmetic mean; 175 ug/m^3 24 hour expected value) will be assessed. This section assumes that the link between Pollutant X and respiratory disease is well established and that the pollutant is known to cause both illness and death.

This section is divided into two subparts--quantifiable and nonquantifiable health benefits.

a. Quantifiable effects

To assess the health benefits resulting from a decrease in Pollutant X, expected reductions in death, medical expenses, and lost work days will be examined. To obtain this estimate the following data are necessary:

- dose-response curves which relate levels of Pollutant X to the incidence of illness and death caused by the pollutant,

- levels of Pollutant X with and without the proposed regulatory option for each area and each year 1/ of the study period,
- population levels for each study area for each year of the study period with and without the regulatory option, and
- an estimate of the following--
  - number and value of work loss days per illness and
  - average costs per illness.

Each of these data needs as well as the calculations used are discussed below.

(1) Dose-response curves. For dose-response curves, the ideal data would indicate the entire curve for each illness with which the studied pollutant is associated, and, for each illness how this relationship is affected by different population characteristics. 2/ The latter data would allow the analyst to more accurately predict the effect on the population at risk. Additionally, such relationships should be' accompanied by confidence intervals which would express the uncertainties of the relationship among pollutant levels and number of illnesses or deaths.

Unfortunately, since appropriate controlled experiments cannot be performed on humans and because the extrapolation of test results from other animals to humans is tenuous, the analyst often only knows a portion (or fragments) of the needed dose-response information. Epidemiology studies provide much of what is known; however, not all confounding factors can be accounted for in such studies. Additionally, due to the scarcity of appropriate studies, the results from one population often must be extrapolated to another population though each has different characteristics and is exposed to different factors. Thus, care must be taken in using such data. The following cautions are advisable, for instance, when secondary data are used:

1/ Other time intervals could be used; however, to simplify the case study, year intervals were employed.

2/ For example, a population with mostly senior citizens will likely be much more sensitive to a given incremental pollutant than would one with a large proportion of persons between twenty and forty years. Population characteristics of interest include: age distribution, overall health, genetic makeup, personal habits and care (e.g., the percent of those who take part in physical fitness programs, of those who smoke), etc.

- the study should try to account for confounding factors (i.e., other pollutants, smoking habits, age, etc.) and
- the pollutant levels examined should encompass the range needed in the considered RIA.

For this case study, the dose-response curves are assumed to be S-shaped 3/ (Liu and Yu, 1976) and the range of results necessary for the analysis are assumed to fall in the linear portion of that curve. The specific functions utilized will be discussed in the "calculation" section below.

(2) Pollutant levels. Sophisticated models which utilize such information as wind and weather patterns, pollutant sources, and topography are available to predict pollutant levels, and they can be used to obtain an estimate of future pollutant levels. However, assumptions must be made for population and industrial growth trends in the study area and should reflect past trends as well as future outlooks. To predict pollution levels with the regulation, assumptions must be made concerning compliance rate and level.

To simplify the present case study, the "without regulation" Pollutant X levels were assumed to increase linearly in each of the study areas (for amounts, see Table 1). For the regulatory alternative considered, a four-year compliance lag time was assumed. During the first year, there would be no reduction in pollutant level; however, a linear decrease over time to the specified level in the fourth year was utilized. Thereafter, the concentration of Pollutant X was assumed to remain constant at the ambient air level specified by the alternative. (Note: variations of this scenario can be examined in the sensitivity analysis.)

(3) Population level. Dose-response equation results are often expressed per population unit. Also; terms in an overall health benefits equation are a function of population level (including mortality, itself a function of population level). Thus, an estimate of the population level is necessary for each year of the planning period. Additionally, if decreased air pollutant levels will significantly affect death, immigration and emigration levels in a given geographical area, two sets of population estimates are needed for the planning period: one set expressing levels with the regulation and the other giving levels without

For this case study, a constant percent growth rate per year is assumed for each of the study areas (see Table 1). The effect of the proposed regulatory option on death, immigration and emigration rates is assumed negligible.

3/ As the pollutant level increases, mortality or illness level initially increases at an increasing rate and continues to increase until the inflection point is reached; hereafter the rate of change begins to decrease at a decreasing rate. The resulting shape is such that the first portion of the curve is concave, the middle portion approaches linearity and the final part is convex.

(4) Value estimates of work loss days and illness costs. The most reliable source for such data is study area surveys, which would include those persons known to have had pollutant-related illnesses. Additionally, hospital and other medical care records could be examined, and medical costs estimated for hospital expenses, cost per physician visit, drug costs, nursing home care costs, etc. However, conducting such studies is often not feasible within the time frame and resource constraints that exist. Alternate sources of information would include Vital and Health Statistics, Statistical Abstracts, and Cooper and Rice's study entitled the "Economic Cost of Illness Revisited" (1976). These will be discussed in more detail in the next section.

(5) Calculations. The general form of the equations used in this section to determine such costs is the following:

$$\text{Change in illness or death} = \left(\begin{array}{c}\text{Expression}\\ \text{relating}\\ \text{illness}\\ \text{or death to}\\ \text{pollutant change}\end{array}\right) \times \left(\begin{array}{c}\text{Expression}\\ \text{reflecting}\\ \text{changes in}\\ \text{pollutant}\\ \text{levels}\end{array}\right) \times \left(\begin{array}{c}\text{Expression}\\ \text{tying}\\ \text{effect to}\\ \text{population}\\ \text{level}\end{array}\right)$$

The first expression is obtained from the applicable dose-response curve 4/ and often is expressed in terms of population units; the second is from the functions determining pollutant level with and without the proposed regulation. The third expression ties the first two to the number of persons in the study area, and this is often expressed in terms of the number of population units. At times this expression may be the regional mortality rate, but the exact form of this expression is determined by the configuration of the information obtained in the dose response term. The number of illnesses avoided is then valued using information on work loss days and direct medical expenses (e.g., hospital, physician and drug costs). Although some studies have attempted to value the number of deaths through a willingness-to-pay survey, this is a controversial undertaking and should not be attempted in RIA's.

The equations 5/ used for the present case study are briefly outlined below. Because air pollution dose-response information is often available only for classes of illnesses rather than a specific condition, morbidity and mortality effects for only two general classes of illness--acute and chronic respiratory- diseases--are included.

(a) Mortality equations--The equations utilized to relate a decrease in Pollutant X with reduction in deaths caused by acute and chronic respiratory diseases are as follows: 6/

4/ Depending upon the amount of information available, this relationship may be made a function of the characteristics of the population at risk.

5/ Most equations are patterned after MATHTECH (1981). These equations do not necessarily need to appear in the text of an RIA.

6/ Note that toxic substances can be examined in this same fashion though the dose-response function used would be different.

Acute: $Q_{ij} = .049 \times \Delta Pol_{ij} \times Mort_{ij}$ (1)

Chronic: $P_{ij} = .125 \times \Delta Pol_{ij} \times Mort_{ij}$ (2)

where

Q_{ij} = reductions in deaths due to acute respiratory disease in study region i for year j

P_{ij} = reduction in deaths due to chronic respiratory disease in study region i for year j

ΔPol_{ij} = the change in Pollutant X levels in region i for year j (annual arithmetic mean in ug/m^3)

$Mort_{ij}$ = yearly mortality (expressed per 1,000 persons) in region i during year j 7/

i = indicates study region and ranges from 1-3;

j = indicates year and ranges from 1-20.

The coefficients .049 and .125 express dose-response information and relate change in pollutant level to number of deaths. These were derived from MATHTECH (1981) by assuming Pollutant X results in only half as many deaths as particulates.

To obtain the total reduction in deaths for the entire region for the planning period, results are summed over i and j. Estimates from the calculations are shown in Table 9.

According to EPA guidance, deaths should be examined relative to excess costs if monetizable benefits are less than costs; however, in this case study benefits exceeded costs.

(b) Morbidity equations--To illustrate the sensitivity of the dose-response term to the population at risk, the following equations for morbidity take into account each subarea population's age distribution and assume that both younger and older individuals are more sensitive to Pollutant X.

The equations for calculating the number of illnesses avoided for acute and chronic diseases are as follows:

Acute: $AM_{ij} = (C_{1ij} \times .003 + C_{2ij} \times .001 + C_{3ij} \times .002) \times \Delta Pol_{ij} \times AD_{ij}$ (3)

7/ This is a function of population size and is often calculated as a percent of population level. The present case study assumed a constant death rate (i.e., .9% of the population per year).

Table 9. Deaths avoided due to the proposed Pollutant X air pollution control regulation by year 1/

j	Year	Acute Respiratory Disease 2/				Chronic Respiratory Disease 2/				Total Deaths Avoided		j
		Urban	Suburban	Rural	Total	Urban	Suburban	Rural	Total	Estimate	Range	
1	1982	0	0	0	0	0	0	0	0	0	0	1
2	1983	3.5	1	.1	4.6	9.9	2.7	.2	12.8	17.4	10.8- 23.9	2
3	1984	7.0	2.4	.1	9.5	19.8	6.3	.4	26.5	36.0	22.6- 49.4	3
4	1985	10.4	3.8	.2	14.4	29.0	9.7	.6	39.3	53.7	33.7- 73.7	4
5	1986	10.7	4.1	.2	15.0	30.2	10.4	.6	41.2	56.2	35.3- 77.1	5
6	1987	11.2	4.2	.2	15.6	31.5	10.7	.6	42.8	58.4	37.3- 79.5	6
7	1988	11.5	4.5	.2	16.2	32.8	10.9	.6	44.3	60.3	38.9- 81.6	7
8	1989	11.9	4.5	.2	16.6	33.6	11.5	.6	45.7	62.3	40.7- 83.9	8
9	1990	12.2	4.6	.2	17.0	34.9	11.7	.6	47.2	64.2	42.5- 85.9	9
10	1991	12.7	4.8	.3	17.8	36.3	12.2	.6	49.1	66.9	45.0- 88.8	10
11	1992	13.0	5.0	.3	18.3	37.1	12.8	.6	50.5	68.8	46.1- 91.5	11
12	1993	13.5	5.1	.3	18.9	38.5	13.1	.6	52.2	71.1	47.6- 94.6	12
13	1994	14.0	5.2	.3	19.5	39.9	13.3	.7	53.9	73.4	49.2- 97.6	13
14	1995	14.3	5.5	.3	20.1	40.8	13.9	.7	55.4	75.5	50.6-100.4	14
15	1996	14.9	5.7	.3	20.9	42.2	14.5	.7	57.4	78.3	52.7-103.9	15
16	1997	15.4	5.8	.3	21.5	43.7	14.8	.7	59.2	80.7	54.1-107.3	16
17	1998	15.7	6.0	.3	22.0	44.6	15.4	.7	60.7	82.7	55.4-110.0	17
18	1999	16.3	6.1	.3	22.7	46.1	15.7	.7	62.5	85.2	57.1-113.3	18
19	2000	16.8	6.4	.3	23.5	47.7	16.3	.7	64.7	88.2	59.1-117.3	19
20	2001	17.2	6.5	.3	24.0	48.6	16.6	.7	65.9	89.9	60.5-119.3	20
Total		242	91	5	338	687	233	12	931	1,269	797.8-1742.2	

1/ The current (and expected) air quality in the region was used as the baseline for these calculations. Thus, the numbers shown represent the number of deaths which would be avoided if pollutant levels were reduced from their present level to that specified by the proposed regulatory alternative. For further information on the baseline used, see Section C.1.(2).

2/ The ranges for the point estimates shown were not included to reduce the complexity of the table. These can be easily calculated for each value since a constant percent variation around the point estimate was assumed for each area (i.e., 4O%, 30% and 20% for the urban, suburban and rural areas, respectively). Only the ranges for the grand total values are shown column 12).

Chronic: $$CM_{ij} = (C_{1ij} \times .006 + C_{2ij} \times .004 + c_{3ij} \quad .005) \times \Delta Pol_{ij} \times CD_{ij} \qquad (4)$$

where:

AM_{ij} = the number of acute illnesses avoided in region i during year j

CM_{ij} = the number of chronic illnesses avoided in region i during year j

C_{gij} = the portion of the population in region i which is in age class g during year j; g = 1 implies 0-13 years; g = 2 implies 13-55 years; g = 3 implies greater than 55 years

ΔPol_{ij} = the change in Pollutant X levels (annual arithmetic mean in ug/m3) in region i for year j

AD_{ij} = annual number of acute respiratory disease incidences in region i for year j

CD_{ij} = annual number of chronic respiratory disease incidences in region i for year j

To reduce the complexity of the calculations, a stable age distribution was assumed for the three study regions during the twenty year planning period. 8/ The coefficients in equations 3 and 4 express dose-response information and were derived from MATHTECH (1981), again assuming Pollutant X results only in half as much illness as particulates.

The results of equations 3 and 4 are valued using estimates of the direct medical cost and the number of work loss days per case. The equations for direct medical expenses are as follows:

Acute: $$ADM_{ij} = AM_{ij} \times AME \qquad (5)$$

Chronic: $$CDM_{ij} = CM_{ij} \times CME \qquad (6)$$

where:

AM_{ij} and CM_{ij} are as defined above for equations 3 and 4

ADM_{ij} = Direct medical expenses saved due to reduction in acute respiratory illness (in 1980 dollars) for region i in year j

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8/ In an actual study, past age distribution trends should be examined as well as those factors likely to influence these trends in the future. Based on this, a function expressing the growth of each age group over time should be developed (provided enough data are available).

CDM_{ij} = Direct medical expenses saved due to reduction in chronic respiratory illness (in 1980 dollars) for region i in year j

AME = Average national medical expenditure per acute respiratory incident (in 1980 dollars)

CME = Average national medical expenditures per chronic respiratory illness (in 1980 dollars)

The equations to value work loss days are as follows:

Acute: $VAWL_{ij} = AM_{ij} \times AWL_i \times AW_i$ (7)

Chronic: $VCWL_{ij} = CM_{ij} \times CWL_i \times CW_i$ (8)

where:

AM_{ij} and CM_{ij} are as defined in equations 3 and 4 above

$VAWL_{ij}$ = Value of reduction in work loss days due to acute respiratory disease incidences avoided for region i in year j

$VCWL_{ij}$ = Value of reduction in work loss days due to chronic respiratory disease incidences avoided in region i for year j

AWL_i = Average number of work days lost per acute respiratory condition for region i

CWL_i = Average number of work days lost per chronic respiratory condition for region i

AW_i = Average daily wage for persons with acute respiratory. disease in region i (in 1981 dollars)

CW_i = Average daily wage for persons with chronic respiratory disease in region i (in 1981 dollars)

The ideal values for AWL_i and CWL_i would be regionally specific estimates derived from a survey conducted in each region. Often there is insufficient time and resources to do this. An alternative is to use work loss day information from Vital and Health Statistics (Series 10, various years) which contains information for the nation as a whole. The present case study utilized this information and assumed that there would be little difference among the regions.

Regionally-specific survey information would also be ideal for deriving AW_i and CW. In lieu of this, wage information from county census reports can be used; however, these do not take into account the value of labor provided by housewives and the value of time loss by persons who are institutionalized or unable to work. Cooper and Rice (1976) calculated the value of work loss days by illness type by taking into account the value of persons not earning a wage. That information was employed in the above calculations.

Table 10 shows the results of morbidity calculations.

b. Non-quantifiable effects

In addition to the reduction in medical costs and work loss days, reduced pollutant levels also result in a decline in the pain and suffering associated with air pollution related diseases. Many illnesses, especially the chronic ones, can be particularly troublesome. For example, a survey from Vital and Health Statistics (Series 10; Number 84) indicates that 25%-50% of persons with chronic respiratory diseases are affected a "great deal" by the condition and that more than 80% are affected "somewhat" to a "great deal."

An additional factor which is difficult to quantify is the anxiety suffered due to the threat of illness or death, and such effects are often imbedded in valuations of visibility or aesthetic benefits. Such benefits, while not possible to separately break out and monetize, should be qualitatively addressed in an RIA and taken into account when benefits and costs are compared.

2. Visibility Effects

Two changes of visibility effects--aesthetic and safety--are consequential. The first results because individuals place value on unobscured views and unpolluted skies. The second results because increased visibility may at times decrease the risks of air and surface travel in polluted areas (Waddell, 1974 MATHTECH, 1981). Each of these visibility effects will be discussed in separate sections below; however, primary emphasis is placed on aesthetic effects.

This section of the report discusses visibility effects in the following order:

a. Aesthetic. effects.
    - Methodology of valuing visibility effects
        - Contingent market techniques
        - Actual market survey technique
    - Case study methodology application
        - Residential area application
        - Recreational area application
        - Existence-preservation area application

b. Safety effects

Table 10. Illnesses avoided due to the proposed Pollutant X air pollution control regulation by year 1/ 2/

j	Year	Acute Respiratory Disease 3/				Chronic Respiratory Disease 3/				Total		j
		Urban	Suburban	Rural	Total	Urban	Suburban	Rural	Total	Estimate	Range	
		thousands of dollars										
1	1982	0	0	0	0	0	0	0	0	0	0	1
2	1983	1,221	394	27	1,642	669	204	13.8	887	2,529	1,492- 3,566	2
3	1984	2,467	931	53	3,451	1,352	482	27.3	1,861	5,312	3,124- 7,501	3
4	1985	3,642	1,413	87	5,142	1,996	732	45.2	2,773	7,915	4,656-11,175	4
5	1986	3,775	1,498	88	5,361	2,069	777	45.3	2,891	8,252	4,851-11,654	5
6	1987	3,911	1,551	89	5,551	2,143	803	46.2	2,992	8,543	5,040-12,046	6
7	1988	4,049	1,605	90	5,744	2,218	831	46.7	3,096	8,840	5,576-12,104	7
8	1989	4,182	1,659	92	5,993	2,292	860	47.1	3,199	9,192	5,423-12,961	8
9	1990	4,332	1,715	93	6,140	2,373	888	47.9	3,309	9,449	5,577-13,327	9
10	1991	4,477	1,772	94	6,343	2,453	918	48.3	3,419	9,762	5,738-13,787	10
11	1992	4,594	1,829	95	6,518	2,533	948	49.2	3,530	10,048	5,928-14,168	11
12	1993	4,774	1,888	96	6,758	2,615	978	49.7	3,643	10,401	6,137-14,665	12
13	1994	4,919	1,948	97	6,964	2,699	1,008	50.0	3,757	10,721	6,325-15,117	13
14	1995	5,082	2,010	98	7,190	2,785	1,041	50.9	3,877	11,067	6,530-15,604	14
15	1996	5,239	2,072	99	7,410	2,871	1,073	51.2	3,995	11,405	6,701-16,110	15
16	1997	5,400	2,136	100	7,636	2,959	1,106	52.1	4,117	11,753	6,934-16,572	16
17	1998	5,563	2,201	101	7,865	3,047	1,139	52.4	4,238	12,103	7,141-17,065	17
18	1999	5,729	2,267	102	8,098	3,140	1,175	42.7	4,358	12,456	9,838-15,074	18
19	2000	5,898	2,334	103	8,335	3,231	1,209	53.5	4,494	12,829	7,567-18,085	19
20	2001	6,068	2,400	104	8,572	3,324	1,244	53.9	4,622	13,194	7,750-18,638	20

1/ The current (and expected) air quality in the region was used as the baseline for these calculations. Numbers shown represent the expense avoided due to reduced illness levels. For further discussion of the baseline used, see Section C.1.(2).

2/ Expressed in 1980 dollars.

3/ The ranges for the point estimates shown for each of the areas were not included to reduce the complexity of the table. These can be easily calculated for each value since a constant percent variation around the point estimate was assumed for each area (i.e., 40%, 30%, and 20% for the urban, suburban and rural areas, respectively). Only the ranges for the grand total values are shown (column 12).

a. Aesthetic effects

There are four primary categories of aesthetic benefits--residential, recreational option, and existence-preservation benefits. 9/ The first represents those benefits which are derived from unobscured views and clear unpolluted skies in the immediate home area, the local community, and the place of work and include the visual quality benefits of recreation undertaken near the home or work (e.g., jogging, walking, picnicking at a local city park, skating, biking, etc.). Recreational visibility benefits are associated with recreation away from one's home community (e.g., camping, hiking, visiting state and natural parks and unique natural areas. etc.). option value represents the benefit an individual receives from preserving the option to use a scarce resource in the future when there is some doubt as to whether this resource will be available at that time. Existence-preservation benefits 10/, are those derived from just knowing that the visibility of a particular area is preserved, even though the individual does not necessarily expect to visit the site. This benefit type is particularly of concern for such unique, natural areas as the Grand Canyon, Yellowstone National Park, and Sequoia National Park.

There are two types of methods for valuing such benefits. 11/ The first, contingent market techniques, obtains the value of visual quality through surveys of how respondents think they would behave if a proposed visibility change were to occur. Such studies must be very carefully designed and monitored since valuations will vary with minor nuances in this techniques application. 12/ Additionally, various types of bias can arise (hypothetical, strategic, information and contingent market). Thus, in designing and conducting contingent market techniques, the following must be carried out:

9/ This division was adopted from MATHTECH (1981) since the definitions are set up so that the benefit groups are additive. This is a major consideration because all benefits must be aggregated.

10/. Sometimes bequest benefits are separated from existence-preservation benefits (Walsh et al., 1978) and represent the willingness to pay to assure that future generations can enjoy these scarce resources. This distinction was not made in this case study because we felt that given the complexity of the surveys which will be outlined in the following pages, it was unrealistic to assume that respondents could bid properly on so many benefit types with definitions only slightly different from one another. Thus, it was assumed that this benefit was included in the existence-preservation bid. This benefit type is examined in more detail in the water regulation case study that follows.

11/ See Rowe and Chestnut (1981) for a more detailed discussion of these techniques.

12/ The "true" value which a person places on an incremental change in visibility is likely measured in each instance; the cause of the variation likely results from the respondents' perceptions of what is being valued. Thus, unless care is taken, what is actually measured may not be what the survey was intended to examine.

- the contingent market and the air quality changes must seem realistic to the respondent,
- the proposed air quality changes must be adequately communicated to the respondent,
- the circumstances surrounding the change in visibility must be carefully defined,
- the effect of income level must be accounted for, and
- the contingent market in which the respondent is bidding must be carefully defined to the respondent.

Examples of contingent market techniques include bidding methods 13/, variations on the travel cost method, household production function approach, rank attributes and voting approaches. 14/

The second method of valuing visibility benefits utilizes actual markets. One approach is based on the premise that people are willing to pay more for a residence with better air quality. 15/ Thus, the amount the individual would be willing to pay for this quality can be revealed by determining price differences between properties which are similar in all respects except air quality. 16/ Studies designed to measure this difference try to examine similar property in areas of differing air quality. Because other factors influencing property value must also be taken into account, such studies require detailed data on:

- property value levels,
- structural characteristics of property examined,
- neighborhood characteristics, and
- neighborhood environmental quality.

A difficulty encountered in property value studies is that often more than just the effects of visibility are measured since other air pollution effects are tied to property value as well, i.e., health and soiling and material damage. Consequently, the results of such studies must often be partitioned to prevent double counting.

The present case study assumed that a series of contingent market surveys would be conducted in the two areas (urban and suburban) which would experience a detectable improvement in visibility. This assumption was made to illustrate how little secondary data 17/ are available for an

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13/ These are probably the best developed of such methods.

14/ For discussions explaining or illustrating these approaches, see Brookshire et al., 1976; Rowe et al., 1980; and Rowe and Chestnut, 1981.

15/ A similar approach examines wage level differences in areas of different air quality.

16/ The theoretical basis for this is hedonic price theory.

17/ Examples of studies which attempt to measure visibility benefits include: Randell, et al. (1974), Brookshire, et al. (1979), SRI International (1980), and Brookshire, et al. (1981).

accurate estimation of visibility benefits and that those which are available are often regionally specific. The assumption illustrates, also, that primary data will usually have to be collected to estimate these benefits. On the other hand, the resources available to conduct such surveys and the delays in obtaining OMB clearance must be taken into account in determining the most feasible approach to dealing with visibility effects.

One set of surveys, to be administered in residential and work areas, was designed to estimate residential visibility benefits by determining the amount a household would pay to achieve a given level of visual quality in the area where respondants live, work and take part in everyday recreational activities. Another set of surveys was designed to determine the additional amount the user of the region's state park (e.g., for special recreational activities such as camping, hiking and fishing) would pay in increased entrance fees to achieve a given level of visual quality at the recreation area. Surveys were carried out at the park, and since the park is used by both residents and non-residents of the study region, both groups were surveyed. However, area residents were instructed that the bid given must be in addition to whatever they would pay for visual quality improvement in their home and everyday recreational area. (The distinctions outlined in this paragraph are necessary to assure additivity.)

The residential visibility benefits shown in Table 11 were estimated with the following assumptions:

- residents on the average will pay annually per household, $5 per mile of increased visual range,
- the average increase in visibility in the urban-suburban areas is approximately ten miles,
- the annual growth rate of households for the twenty-year planning period follows closely that of the projected population growth, and that
- there is an average of 2.78 persons per household.

Recreational visibility benefits are also shown in Table 11. The assumptions for these calculations were as follows.

- The area's initial visitation rate was 100,000 visits per year.
- An average fee increase (from the survey) of $3 per visit was assumed. Of this, $2 represented benefits for increased visibility and $1 was from reduced forest vegetation damage (discussed under ecological effects).

Table 11. Quantifiable visibility benefits due to the proposed Pollutant X air pollution control regulation by year 1/

j	Year	Residential Benefits 2/ 3/	Recreational Benefits 3/ 4/	Option Value Benefits 3/ 5/	Existence-Preservation Benefits 3/ 6/	Total Visibility Benefits Estimate	Total Visibility Benefits Range
		thousands of dollars					
1	1982	0	0	0	0	--	--
2	1983	5,454	204	128	382	6,168	4,858-7,274
3	1984	11,026	206	129	285	11,646	9,220-13,866
4	1985	18,575	208	130	389	19,302	15,363-23,033
5	1986	18,776	212	132	394	19,514	15,532-23,284
6	1987	18,979	216	134	398	19,727	15,701-23,539
7	1988	19,184	218	136	402	19,940	15,870-23,792
8	1989	19,373	222	136	404	20,135	16,026-24,026
9	1990	19,600	226	138	409	20,373	16,216-24,310
10	1991	19,812	228	140	413	20,593	16,390-24,572
11	1992	20,026	232	142	417	20,817	16,568-24,838
12	1993	20,243	236	144	422	21,045	16,750-25,110
13	1994	20,462	240	145	426	21,273	16,931-25,383
14	1995	20,694	242	147	431	21,514	17,123-25,669
15	1996	20,907	246	149	435	21,737	17,301-25,935
16	1997	21,133	250	151	440	21,974	17,488-26,218
17	1998	21,366	254	152	444	22,216	17,682-26,506
18	1999	21,592	258	154	449	22,453	17,870-26,790
19	2000	21,826	262	156	453	22,697	18,064-27,080
20	2001	22,051	266	158	457	22,932	18,252-27,360

1/ Entries are in constant 1980 dollars.

2/ Includes only the urban and suburban areas.

3/ The ranges for the point estimates are not shown to reduce the complexity of the table, These can be easily calculated for each value, however, since a constant percent variation around the point estimate was assumed for each benefit type (i.e.,2O%, 152, 20% and 25% for residential, recreational, option value and existence-preservation benefits, respectively). Only the. ranges for the grand total values are shown (column 8).

4/ Includes only users of the State Park in the area.

5/ Includes nonusers of the State Park from all three study areas as well as users of the park.

6/ Includes all three study areas.

- The expected demand growth rate 18/ was 1.5 percent per year for the twenty-year planning period.

The calculation method used for both benefit types was simplified since the bid was assumed not to vary by income and other socio-economic characteristics. In an actual study, calculations should be performed for each socio-economic grouping and then summed. Equations relating visibility change, socio-economic characteristics, and willingness-to-pay, would have to be worked out. One such equation developed by MATHTECH (1981) has the following form:

$$B = nY^a \Delta V^c \tag{9}$$

where

B = willingness-to-pay per household (or visit) per year

Y = yearly or household income

ΔV = improvement in visibility

n = constant term

a,c = elasticities of income and visibility, respectively, associated with willingness-to-pay for improved visibility

To obtain an estimate of the total benefits, the results of the equation are multiplied by the number of households (or by the number of visits in the case of recreational benefit) in the study area. Because the number of households (and visits to the state park) is a function of population size, this number should change through time to reflect the expected population growth.

To estimate option value benefits, we assumed that both the residential and park surveys were utilized. Users of the park were asked what additional amount they would be willing to pay to assure a given level of visual quality at subsequent visits to the park. (Respondents were instructed that this would be in addition to the amount paid to achieve a given level of visual quality at the park.) Using the residential survey, individuals currently (i.e., within the last five years) not using the park were determined and asked the amount they would pay per year to assure, at a later time, that the park would have a given level of visual quality when they finally did visit it. 19/ A survey would have to be conducted in the

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18/ Note: this rate takes into account both the effect of population growth and the effect of increased attractiveness of the area due to increased visual quality.

19/ Note that a distinction must be made between the option value bid and the existence-preservation (see Footnote 20 for an explanation of how this might be done).

rural area, also, to obtain an option value estimate for rural households, since the residential study itself was limited to the urban and suburban areas.

The option value benefits shown in Table 11 were calculated using the following assumptions:

- Park users will pay an additional $.50 per year per visit -in user fees to assure that a certain visual quality will be maintained at future visits.

- Approximately 40 percent of the region's households have not visited the park within the last five years and these households. will pay $.50 each year to assure a given level of visual quality at the park when they visit it at a later date.

A particular methodology used to estimate existence-preservation aesthetic benefits is that employed by Greenley, et al. (1978) and Schulze, et al. (1981). The method measures the willingness-to-pay of nonusers of a particular area (e.g., a recreational area, a historical monument, a unique natural area) by asking these individuals how much they would pay to improve the areas's visual quality even though their probability of use is low.

In the present hypothetical case study, such a question is included in the residential survey regarding the preservation of state park air quality. When used, however, the survey must clearly distinguish between nonusers and users and clearly indicate that the amount paid for such air quality preservation would be in addition to that paid to improve visual quality in the residential, work and daily recreation area. Also, a distinction must be made in the respondent's mind between the existence-preservation bid and the option value bid. 20/ As in the case of option value, a survey would also have to be conducted in the rural area to obtain an option value estimate for rural individuals, since the residential study itself was limited to the urban and suburban areas.

Aesthetic existence-preservation value estimates for the region are shown in Table 11. These were based on the following assumptions:

- the appropriate questions worded to avoid bias were added to the residential survey,

- a significant sample of state park nonusers was found,

20/ A method which might be used to make this distinction would be to first question the respondent about their existence-preservation bid. The respondent would then be asked to assume that their probability of visiting the park in the next several years is high and based on this assumption what amount, in addition to their existence-preservation bid, would they pay to assure a given level of visual quality at that time.

- the average nonuser would pay $1 per year (in constant dollars), to improve the visual quality in the state park to the level afforded by the regulatory option, 21/ and

- the $1 annual fee cited by the nonuser would be a reasonable estimate of the existence-preservation benefits for all householders.

b. Safety effects

although decreased visibility due to air pollution can cause safety problems for air and surface (automotive) travel, separating this effect from other safety factors can be difficult. Regression models could be developed to aid in this attempt; however, such studies are costly and time consuming. As such, these effects will be left unquantified in this case study. Moreover, in most cases, safety effects would be expected to be small.

3. Material Damage and Soiling

Although air pollutants can cause property damage either through deterioration or soiling, only the latter type of damage will be examined in this case study (primarily because sufficient data are not available regarding deterioration). Generally, however, the benefit assessment for both types of material damage will be similar.

Soiling results from the accumulation of air particulate pollutants on exposed surfaces (i.e., windows; walls, draperies, etc.) to such a degree that these surfaces appear “dirty" and require cleaning. (Obviously more severe accumulations can both discolor and weaken many fabrics, especially when the particulates are abrasive or corrosive.) Thus, a reduction of air pollution levels will result in less time and money used to maintain comparable cleanliness. 22/ Households, businesses, industries, government agencies and all other persons or companies owning buildings or structures in the affected area will benefit. However, current data are available to assess the effects only on households. (MATHTECH is currently developing a method to assess the industrial sector; however, the documentation of this method is currently unavailable.) Thus, this section will focus on the effect of soiling on the household sector.

21/ Again a simplified method of calculation was used. In an actual case study, data should be examined relative to socio-economic characteristics. The form of an appropriate equation would be similar to that outlined above for equation 9.

22/ Another possible effect is the soiling or damage of a historic building, work of art or artifact. In this case, existence-preservation benefits would have to be addressed as well.

Two approaches may be used to estimate the benefits from reduced soiling--physical damage functions and behavorial models (MATHTECH, 1981). The data requirements of the former are extremely burdensome since establishing the physical damage functions for specific materials (e.g., window glass, painted woodsiding, brick, limestone) requires estimating the exposure of these materials to differing levels of air pollution (i.e., particulate matter) and relating this to an estimate of damage (e.g., for glass this would mean a loss of transparency). The damage function results must then be translated into economic costs in terms of cleaning and repair (preventative measures should also be taken into account). An example of such a study methodology is found in Beloin and Haynie (1975).

Behavorial models bypass the need for damage functions by directly measuring how people respond to increased soiling. Such approaches include: (1) property value studies, (2) surveys of frequency and expenditures for cleaning activities (hereafter called cleaning survey studies), and (3) economic demand and supply models (MATHTECH, 1981). Property value studies have already been discussed in this chapter's section on visibility; again, the weakness of such studies is their inability to separate soiling effects -from health and aesthetic effects.

Cleaning survey studies often use the paired cities (or areas) approach and compare the frequency of household maintenance and cleaning activities in areas with differing levels of air pollution. Examples of such studies include: Michelson and Tourin (1967), Booz, Allen and Hamilton (1970), Nariayan and Lancaster (1973), Liu and Yu (1976), Brookshire, et al. (1979), and Cummings, et al. (1981). The disadvantages of such studies include their inability to account for all confounding variables, the fact that their results are specific to only a small number of paired cities or sites, and the difficulties they pose in determining the proper form for frequency of cleaning functions.

The economic demand and supply model approach is based on the premise that the value to society of reduced soiling should be measured by the aggregate amounts members of society would be willing to pay to attain the same level of cleanliness for less labor and expense. Measuring this requires knowing: (1) the reduced out-of-pocket expenditures and (2) the effect that cost savings will have on prices, since reduced cost for "cleanliness" can result in an increased demand (and in turn an increased price) for goods and services associated with cleaning (MATHTECH, 1981). This approach represents the most advanced method for estimating soiling benefits. Examples of such studies include: Watson and Jaksch (1980) and MATHTECH (1981).

For this case study, the economic demand and supply model approach was not utilized, however, due to a lack of available data. (The Watson and Jaksch (1980) study is currently unpublished and the MATHTECH approach, due to its preliminary nature, is currently unavailable in enough detail to be utilized.) Instead, the benefits were based on the Cummings et al. (1981) study which was chosen because it includes both the expenditures for cleanliness and the opportunity cost of labor.

In estimating the relationship between damages and pollutant levels, Cummings, et al. took into account many factors including income level and costs in households where help is hired and costs in households where help is not hired. From this study, it was determined that each 1 ug/m³ decrease in annual average particulate matter levels resulted in a decrease of $6.63 dollars per year per household in cleaning and labor costs. Assuming that Pollutant X's soiling effects are only one quarter as severe as those of particulate matter, a simplified expression relating reduced costs and changes in Pollutant X levels would be:

$$S_{ij} = (1.66\ \Delta P_{ij})\ B_{ij} \tag{10}$$

where

S_{ij} = the reduction in cleaning expenses for region i in year j

ΔP_{ij} = change in Pollutant X level in region i for year j

B_{ij} = number of households in region i for year j

The benefit estimates of reduced soiling that are associated with the regulatory option considered are shown in Table 12. (Benefit estimates were made for the urban and suburban areas only, since Pollutant X levels are assumed low enough in the rural area that little or no soiling occurs.)

4. Ecological Effects

The ecological effects of air pollution result from the impact of pollutants (usually oxidants and sulfur dioxide) on plant life and animal populations. The major documented effects, however, have been on vegetation; thus this section will primarily address the effect of air pollution on plants though much of what is proposed is also applicable to animal populations when a significant effect is demonstrated.

There are three classes of ecological effects--commercial, ornamental and natural. Each will be separately assessed below.

a. Commercial effects

Commercial effects result when commercial plants are damaged. Examples include agricultural crops, timber production tracts, Christmas tree farms, and floral and foliage plant crops. Air pollution can cause damage either to the foliage or the fruit and can result in their reduced values. Additionally, plant growth (and in turn fruit and flower growth) can be reduced either through foliage damage or through physiological effects, which, though not resulting in overt damage, do result in reduced yields.

Several methods exist to estimate the benefits resulting from reduced air pollution damage to crops. One approach is to directly value the amount of production lost per year due to the air pollutant examined. Examples of such studies include: Benedict, et al. (1971) and Liu and Yu (1976). However, a more recent approach is to measure producer and consumer surplus

Table 12. Reduced soiling benefits due to the proposed Pollutant X air pollution control regulation by year 1/

j	Year	Urban 2/	Suburban 2/	Total Estimate	Total Range
		------------------thousands of dollars------------------			
1	1982	0	0	0	0
2	1983	4,690	1,446	6,136	4,675- 7,598
3	1984	9,474	3,415	12,889	9,838-15,941
4	1985	13,962	5,183	19,145	14,618-23,673
5	1986	14,868	5,495	20,363	15,547-25,179
6	1987	15,017	5,687	20,704	15,735-25,673
7	1988	15,546	5,882	21,428	16,285-26,570
8	1989	16,060	6,079	22,139	16,826-27,452
9	1990	16,632	6,288	22,920	17,419-28,421
10	1991	17,132	6,496	23,628	18,046-29,210
11	1992	17,756	6,708	24,464	18,593-30,335
12	1993	17,332	6,924	25,256	19,195-31,317
13	1994	18,933	7,144	26,077	19,819-32,335
14	1995	19,531	7,369	26,900	20,368-33,232
15	1996	20,119	7,598	27,717	21,167-34,267
16	1997	20,735	7,832	28,567	21,711-35,423
17	1998	21,365	8,214	29,579	22,480-36,678
18	1999	21,998	8,313	30,311	23,036-37,586
19	2000	22,645	8,560	31,205	23,716-38,694
20	2001	23,303	8,802	32,105	24,519-39,691

1/ Expressed in constant 1980 dollars.

2/ The ranges for most entries are not shown to reduce the complexity of the table. These, can be easily calculated for each value, however, since a constant percent variation around the point estimate was assumed for each area (i.e., 25% and 20% for the urban and suburban areas, respectively). Only the ranges of the grand total values are shown (column 6).

changes traceable to reduced damage levels (Leung et al., 1981; Page et al., 1981). This latter approach will be used in this case study. Since Pollutant X is assumed to be regionally specific, the increased yields due to the reduction of this pollutant will likely not affect the prices received for the crops in the region; thus, since consumer surplus will not be affected, it will not be estimated 23/.

Figure 2 illustrates how the change in producer surplus can be estimated if the appropriate data are available. S_{1ij} represents the crop i supply curve in year j if Pollutant X is not regulated and S_{2ij} is the crop's supply curve in year j with the regulatory option. (There would be a set of such curves for each year of the planning period.) For reasons stated previously, the price P_i, is constant in both situations. The change in producer surplus resulting from reduced damage in year j is represented by the shaded area 0cd which is estimated as follows:

$$\Delta PS_{ij} = (P_i \times Q_{2ij} - f_2) - (P_i \times Q_{1ij} - f_1) \qquad (11)$$

where

ΔPS_{ij} = the change in producer surplus for crop i in year j

P_i = the price of crop i in constant dollars

Q_{1ij} = quantity of crop i produced in year j if Pollutant X is not regulated

Q_{2ij} = quantity of crop i produced in year j if the regulatory option is chosen

$$f_1 = \int_0^{Q_{1ij}} S_{1ij} \, dQ$$

$$f2 = \int_0^{Q_{2ij}} S_{2ij} \, dQ$$

The total change in producer surplus each year is the summation of ΔPS_{ij} for all crops.

To estimate APS empirically the following are needed:

23/ In a national study, consumer surplus will have to be estimated since prices would likely be affected. Leung, et al. (1981) uses this method.

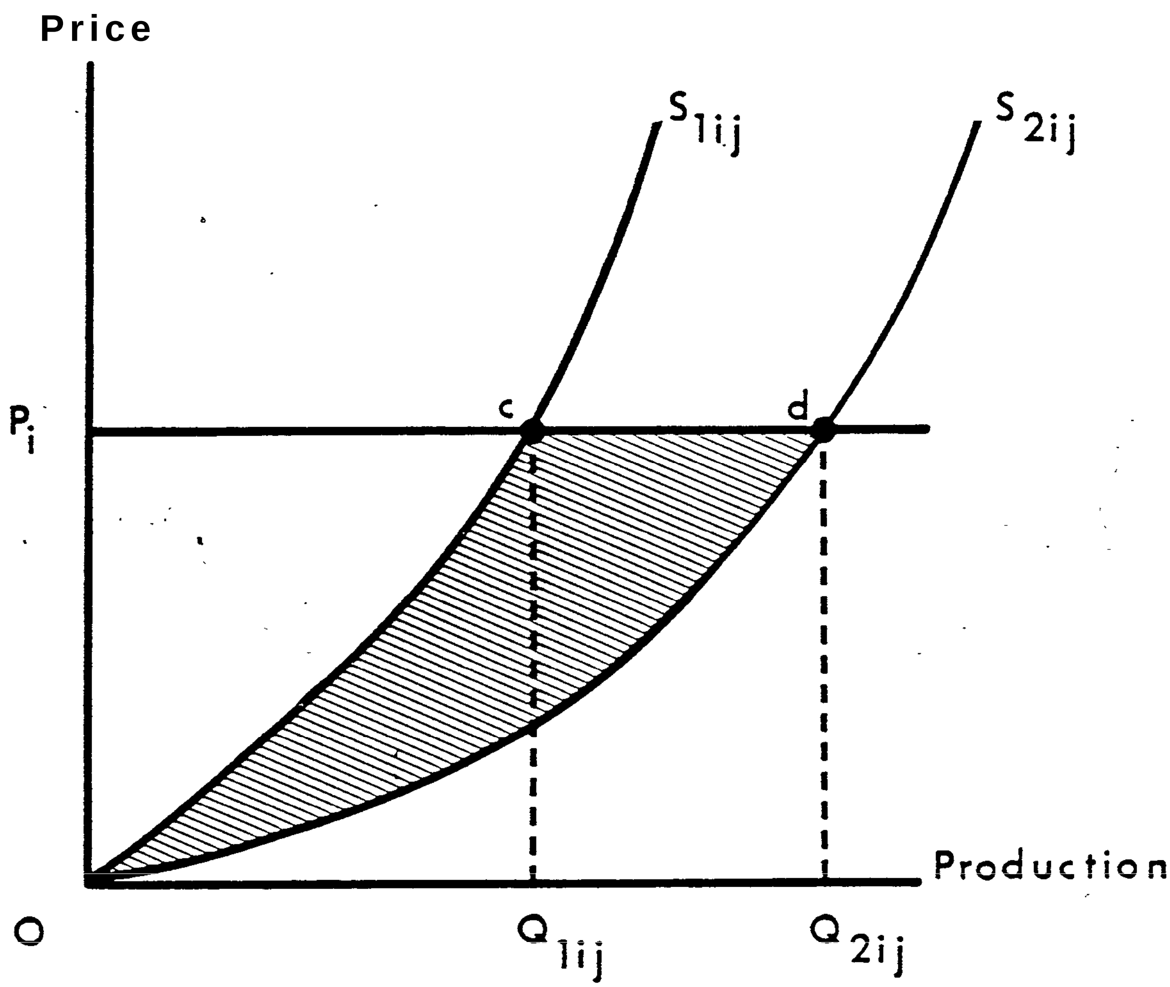

Figure 2. Illustration of producer surplus where S_{1ij} represents crop i supply levels in year j without the regulatory option and S_{2ij} represents crop i supply levels in year j with the regulatory option. 1/

1/ Patterned after Page, et al. (1982).

- A damage function must be determined to relate pollutant levels to plant damage. This function should take into account other factors which affect yield (e.g., temperature, humidity, annual amounts of sunlight, pests, etc.) and such a function is necessary for each crop type examined since sensitivity varies by species and variety. The information for such functions can be obtained from studies examining the effects of air pollutants on specific crops and examples include: Heagle, et al. (1972, 1974, 1979 a and b), Oshima (1973), Shannon (1974), Larsen and Heck (1976), Oshima, et al. (1976 and 1977), Heggestad, et al. (1977), McLaughlin, et al. (1979), Loucks, et al. (1980), and Sprugel, et al. (1980). Additionally, EPA sponsors the National Crop Loss Assessment Network project established to examine both the physical and economic damages to crops which result from air pollution. The project's study data are just beginning to enter the literature.

- An estimate must be made of crop yields for the planning period with and without regulation. Such an estimate is needed for each year of the planning period and should take into, account the following factors:
  - increased per acre yields due to improved strains and farming techniques during the planning period,
  - air pollutant levels and the cropland area affected each year,
  - cropland lost each year due to non-agricultural development, and
  - results of the dose-response function

  Data sources for such information include OBERS (1972 and 1975), 24/ agricultural extension studies, agricultural statistics, and area primary data collections.

- Estimates are needed, also, of supply curves with and without regulation. Examples of studies in which such curves have been estimated include. Leung, et al. (1982) and Page, et al. (1982).

- The functions must also include estimated annual prices of the affected crop.

To calculate ΔPS for the case study, the following assumptions were made:

- Only one crop type, crop i, will be affected. 25/

24/ A regression analysis will likely have to be used along with OBERS to update the projections.

25/ Note: the procedure would be similar for all crop types. After calculations would be made for each, all would be summed.

- Current crop losses due to Pollutant X are estimated at 8 percent per year. 26/ This level is expected to reach 10 percent by the end of the planning period.

- Approximately 50,000 acres are currently affected by Pollutant X, and this amount is expected to increase by approximately 1 percent per year during the study period.

- Per acre yields are expected to increase according to OBERS projections, and current yields are 100 bushels per acre in areas unaffected by pollution X damage.

- Current prices are 32.50 per bushel.

- The regulatory option considered would reduce Pollutant X levels to non crop damaging levels once the ambient air quality standard is reached.

- The supply curve estimate was patterned after that of Page, et al. (1982), though this form may not be applicable in all situations. The curves were assumed to have a constant elasticity of supply (.7) over the relevant range and a form reflected by the equation:

$$Q = aP^b \tag{12}$$

  where Q is the quantity produced each year 27/, P equals price, and b is the elasticity of supply. The parameter, a, is solved for each year since all other equation values are known. This parameter fixes the position of the supply curve.

The results of the calculations are shown in Table 13.

b. Ornamental effects

Ornamental effects result when air pollutants damage shrubs, lawns, shade trees, and other plants used to landscape homes, businesses, cemeteries, parks, and other public places to such an extent that additional maintenance and replacement costs are incurred. However, little current information is available to assess this effect. Thus, the benefits resulting from reduced care and necessity of replacing ornamentals will not be quantified for this case study.

26/ Note: Since a wide range of damage levels in the affected areas exists, the calculations would be performed by subarea so chosen as to minimize damage variances within them. However, to simplify the calculations, the present study assumed that the variance level was low.

27/ To form the pair of supply curves required each year, one of the curves would have Q equal to yields without pollution and the other would have Q equal to yields with regulation.

Table 13. Ecological benefits due to the proposed Pollutant X air pollution control regulation by year 1/

j	Year	Commercial Plant Systems 2/	Natural Systems 2/ Recreation	Option	Existence-Preservation	Total Value	Range
		---thousands of dollars---					
1	1982	0	0	0	0	0	0
2	1983	145	146	128	1,528	1,947	1,487-2,215
3	1984	335	147	129	1,540	2,151	1,640-2,468
4	1985	670	149	130	1,556	2,505	1,908-2,909
5	1986	674	151	132	1,576	2,533	1,928-2,941
6	1987	678	154	134	1,592	2,558	1,949-2,967
7	1988	681	156	136	1,608	2,581	1,966-2,992
8	1989	684	158	136	1,616	2,594	1,976-3,008
9	1990	707	160	138	1,636	2,641	2,012-3,064
10	1991	730	162	140	1,652	2,684	2,043-3,115.
11	1992	753	163	142	1,668	2,726	2,077-3,163
12	1993	776	167	144	1,688	2,775	2,114-3,220
13	1994	795	170	145	1,704	2,814	2,145-3,265
14	1995	814	171	147	1,724	2,856	2,177-3,315
15	1996	833	174	149	1,740	2,896	2,202-3,366
16	1997	852	177	151	1,760	2,940	2,241-3,413
17	1998	871	179	152	1,776	2,978	2,271-3,457
18	1999	903	182	154	1,796	3,035	2,315-3,523
19	2000	936	184	156	1,812	3,088	2,355-3,587
20	2001	969	187	158	1,828	3,142	2,388-3,660

1/ Expressed in constant 1980 dollars.

2/ To reduce the complexity of the table, the ranges for most entries are not shown. These can be easily calculated for each value, however, since a constant percent variation around the point estimate was assumed for each,benefit type (i.e., 25%, 15%, 25% and 20% for commercial, recreation, option and existence-preservation benefits, respectively). Only the ranges of the grand total values are shown (column 8).

c. Natural ecosystem effects

Natural ecosystem effects consist of recreational, option value and existence-preservation benefits. 28/ (Bequest benefits are not included separately due to reasons outlined in Footnote 10.) The first results when individuals walking, running, biking, etc. in natural areas gain satisfaction because these areas are not damaged by air pollution. Assessing these values is possible with a carefully designed willingness-to-pay survey similar to that- described in this chapter's visibility section. (A travel cost approach could also be used if a proper study site could be found.)

This present case study assessed the recreational benefits of natural ecosystem effects by employing the following assumptions:

- Reduced damage in a hypothetical state park was an assumed $1 or 1/3 of the total average bid established in the visibility survey based on questions in the survey designed to separate these from other Visibility benefits.

- The suburban area surveyed contained several natural areas that the survey indicated were used by 10 percent of the suburban residents. Survey questions indicated that such persons would pay an extra $3 29/ per year to realize the level of reduced damage 30/ resulting from the proposed regulatory option.

These benefit estimates are shown in Table 13.

For the option value estimate, both residential and park user surveys were utilized as outlined in the visibility section for this benefit type; however, in this case, the questions would focus on the respondent's bid to assure, for future visits, a given level of reduced vegetation damage rather than visual quality. The option value benefits, shown in Table 13, were estimated using the following assumptions:

28/ An additional type of benefit can result because natural systems are often interconnected, and one system may often affect the environmental quality of another area. For example, forests in a watershed help regulate the mineral and chemical composition of the water entering nearby streams, since mature systems hold minerals and nutrients (e.g., nitrates, potassium, sodium, calcium, etc.) in tight pools. As the forest becomes stressed (e.g., vegetative damage and species composition change), these pools may begin to release more of these materials into streams, and this in turn affects water quality as well as the biota found in the streams. However, since little data exist to allow an evaluation of specific sites, this effect will not be addressed in this case study. In certain circumstances, such effects may need examination (Smith, 1974).

29/ This is assumed to be in addition to their bids for visibility effects. In an actual survey, this must be established to assure that values can be added.

30/ Note: determination of these levels may be difficult.

- Park users will pay an additional $.50 per visit in user fees to assure a given level of reduced vegetation damage for future visits to the park.

- Regional households not currently using the park would pay approximately $.50 per year to assure that when they do use the park a given level of reduced vegetation damage will be apparent.

Existence-preservation values associated with natural areas result because the affected natural areas and species may have value because they are rare (endangered, threatened or unique), and both users and nonusers derive pleasure from their continued existence per se. Again, a carefully designed willingness-to-pay survey could be used to value this. For the case study, the following scenario was developed 31/:

- The state park contains an area of virgin forest which, according to recent studies, has shown foliage damage, reduced species and a shift in species composition. These effects have been shown to primarily result from Pollutant X damage, and if the regulatory option considered is implemented these effects should decrease substantially. The area is unique because few uncut forests of this type exist in the United States.

- To assess the existence-preservation value of this area among the people in the study area, the residential visibility survey was again utilized with questions added dealing with the preservation of the forest itself (as opposed to the visibility in the park). The bid, $4 per year, from nonusers of the park was felt to provide the best estimate. In asking the survey question, it was made clear that this $4 was in addition to the $1 bid for increased visibility in the area. 32/

The estimates of existence-preservation benefits are shown in Table 13.

5. Aggregation of Benefits

As was indicated previously, two levels of aggregation have to be performed in a benefits analysis. The first involves a summation across study units (e.g., regions, counties) and the second aggregates across benefit types. In this case study, the summation across study units was performed for each benefit type. This procedure is often used for benefit analysis, since this aggregation is usually straightforward (provided the study design and data collection are carefully organized).

31/ The distinction was very carefully made between the existance-preservation bid and the option value bid in a manner similar to that outlined in Footnote 20.

32/ Often a total existence-preservation bid may be first elicited. Following that, the respondents are then asked to partition that bid by the different factors which influence that bid--visibility, natural surroundings, etc.

The aggregation across benefit types is not always as easily accomplished, since estimates for different benefit types frequently overlap and can result in double counting. Thus; as cautioned previously, the analyst must be aware of what each measurement technique used actually measures. In this case study, the techniques used were carefully chosen and defined to avoid such double counting; hence, its results can be directly added. However, this may not always be the case in benefit analyses, since secondary data may have to be relied on and their calculations may not always be directly applicable. If overlap is suspected, a method of partitioning the overlapping estimates should be developed.

Information for this can be obtained from empirical studies which, though they used techniques similar to those suspected of overlap, did attempt to partition the results into specific benefit types. Examples of such studies include Brookshire, et al. (1979) and Cummings, et al. (1981).

The aggregate benefits for this case study are shown in Table 3.

D. Social Costs

This section presents the social costs of implementing the Pollutant X air pollution control regulation. These costs are defined as the value of goods and services lost by society resulting from (1) the use of private resources to comply with a regulation, (2) the reduction in output attributable to compliance, and (3) the use of government resources to implement a regulation. Past analyses usually focused only on those costs incurred by directly-affected private parties. The total social costs presented here, however, include all compliance costs (net of transfers), governmental regulatory costs, deadweight welfare losses, and adjustment costs. The distributional effects of these costs are not explicitly considered in the measure of the total social costs; however, they are intrinsic to some costs calculations (i.e., adjustment costs) and they are presented in the economic impacts section.

The total social costs of regulatory compliance should be ideally estimated in a dynamic,. general equilibrium framework which measures over time all of the direct and indirect responses to the regulation in all directly and indirectly affected markets. Since in most cases, however, the time and resources required to perform such an analysis would be prohibitive, practicability dictates that a simpler conceptual framework of a static, partial equilibrium analysis be utilized. As long as the study indicates the equilibrium points chosen for the analysis and defines the inherent biases of these selections, such a static analysis is conceptually acceptable.

Given the framework of a static, partial equilibrium analysis, the procedures for estimating the total social costs should not differ substantially from those of current agency cost analyses. The firm's compliance costs (the private sector, real resource costs) would still constitute the major portion of the total social costs, and they would continue to be based largely on engineering cost estimates. Though constituting a much smaller portion of social costs, the other three types of costs -- government regulatory, deadweight welfare, and adjustment -- must also be calculated.

In this case study's calculations of the above four types of costs, the following industry-related assumptions were made:

- Firms in three regional industries--A, B and C--will be affected by the proposed Pollutant X air pollution control regulation.

- The proposed regulation will require that, new pollution abatement technology be added to existing and new manufacturing plants in the affected industries.

- No charge will occur in the operating efficiency of the affected plants.

- Economies of scale exist in each industry's plants, and three model plant sizes will reflect such major economic differences.

- Industries A and B employ a single major process, and each industry's firms will be represented by a combination of small, medium, and large model plants. Industry C employs two major processes--Process 1 is an old process, Process 2 is a newer one --and all plants are relatively large.

- Model plant results will be aggregated to industry levels by multiplying each model by the applicable number of small, medium, and large plants in each industry.

The following four subsections will detail the procedures applicable to determining the four types of social costs noted above.

1. Private Real Resource Costs

Calculating private sector real resource costs requires estimating the investment costs, the annual operating and maintenance costs, and any additional annual regulatory costs incurred by the private sector. The procedures for estimating these costs are well documented by EPA.

Briefly, such estimates involve the following:

- Delineating the geographic region of study and determining for that area the current and projected baseline air quality, the sources which emit the regulated pollutants, the current and projected emission rates from each source, the relationship between each source's emission rate and the ambient air quality, and the current and projected level of pollutant control at each source (If feasible, “model regions" may be utilized to perform the analysis.)

- Calculating equipment, material, installation, operation and maintenance costs for each feasible control option by source taking into account cost differences between new and existing plants

- Calculating emission reductions attainable with each control option (or combination of options)

- Reviewing control options to reject those which are less cost-effective and defining a chain of pollution reduction control options for each source

- Compiling a constrained, least-cost optimization program which would be linked to an air quality model based on the emissions-rate-to-air-quality relationship

- Computing the least-cost pollution control strategy for achieving the required ambient air quality.

The least-cost strategy defines the control options and their associated investment, operation, and maintenance costs. These costs are summed to obtain the compliance costs of the regulatory action.

Traditionally, compliance cost estimates have represented the final results of a cost analysis; however, in the total social cost approach, the compliance cost estimates are incorporated into a static partial equilibrium analysis of supply and demand to determine the probable changes in price and output resulting from regulation. The compliance costs for the resulting post-regulation 33/ output level are then estimated as a proxy for private sector real resource costs. The steps followed in the present analysis are designed to estimate the (1) revenue requirements necessary to recover the costs of compliance, (2) vertical shift in supply, and (3) changes in output and prices due to regulation. The calculations performed for each of these steps are discussed below.

The revenue requirements necessary to recover the costs of compliance are estimated as the price increase at each level of output required to maintain a firm's profitability at the precontrol level. The method of estimating this required price increase is based on the discounted cash flow procedures used to estimate the present values of pollution control costs. A detailed discussion of these procedures is presented in the economic impact section (Section E) of this report.

Briefly, the discounted cash flow procedures produce an annual percent price increase "required" by each model plant in each industry. The annual percent increases are averaged for each model plant in an industry and a weighted average price increase based on production levels of the model plants is determined for the industry. The percent price increase is then multiplied by the pre-regulation price to determine the average incremental price increase (ΔC) required by all firms in the industry to maintain pre-regulation profitability.

Once the required price increase has been projected and information on the demand and supply elasticities is available, the changes in output and prices due to regulation can be calculated. 34/ To estimate the post-regulation price and quantity equilibrium, the supply and demand functions can be estimated from the supply and demand elasticities -and the pre-regulation price and quantity. This process produces linear demand and supply functions:

33/ Throughout this section, reference is made to the pre- and post-regulation characteristics of the industries. This terminology is used to distinguish the differences between the characteristics of the industry _without_ regulation (baseline) and the characteristics of the industry _with_ regulation. This terminology is _not_ meant to imply any specific time frame.

34/ This approach goes beyond the guidance in Appendix B, which suggests that for most purposes it is sufficient if the supply elasticity is assumed to be infinity (perfectly elastic).

$$P_D = a + bQ_D \tag{13}$$

$$P_S = c + dQ_S \tag{14}$$

where

P_D = demand price,

a = intercept of the demand function,

b = slope of the demand function,

Q_D = demand quantity,

PS = supply price,

C = intercept of the supply function,

d = slope of the supply function, and

Q_S = supply quantity.

The industry is in equilibrium when demand and supply intersect at a quantity Q_1 such that

$$Q_1 = \frac{a-c}{d-b} \tag{15}$$

$$P_1 = a+b\,\frac{a-c}{d-b} \tag{16}$$

For the purpose of estimating changes in output, it is necessary to consider only the shape of the functions in the relevant range of study i.e., near projected equilibrium. The assumption of linearity over this range simplifies the calculations and should not result in significant estimation errors. The required price increase (ΔC) in each industry is added to the supply curve and the new equilibrium price and quantity are:

$$Q_2 = \frac{a-c-\Delta C}{d-b} \tag{17}$$

and

$$P_2 = a+b(\frac{a-c-\Delta C}{d-b} \tag{18}$$

Given the new output and price level, the compliance expenditures--which represent the opportunity costs of the resources used to achieve compliance--can be calculated. Assuming the private costs of the resources used to achieve compliance accurately reflect their value in alternative uses, the private sector real resource costs of compliance are given by the following equation:

$$PSC = \sum_i (P_i A_i Q_2) \quad (19)$$

where

PSC = private sector real resource costs,

P_i = the price of resource i,

A_i = the amount of resource i required to achieve compliance per unit of output,

Q_2 = the output level with regulation,

i = indicates the resource used (labor, land, equipment, etc.)

This equation, in its simplest form, defines the sum of the fixed and variable compliance costs at the post-regulation output level. The compliance costs, are considered on a before-tax basis, since the resources, would be taxed in the alternative use. These costs, after netting out transfer payments (some taxes and insurance), reflect the private sector, real resource costs of regulation.

The above discussion assumed that the production characteristics, pollution control technology effects, and the engineering estimates of the firms' compliance costs have already been developed. The relevant industry characteristics are the number of firms, average annual plant production, annual industry production, and average product price. These characteristics for each industry are presented below.

Industry	Number of firms	Avg. annual plant production	Annual industry production	Average product price
A	130	18,250	2,372,500	$153.85
B	66	267,800	17,674,800	$27.05
C	8	1,451,724	11,613,792	$29.00

The levels of emission reduction and solid waste generation for the selected pollution control technology for each industry analyzed in this study are the following:

Industry	Percent emission reduction	Avg. annual tons of solid waste generated
A	94	750
B	95	1,125
c	97	1,425

The firm's compliance costs for the selected technologies include the investment costs, annual operation and maintenance costs, annual solid waste disposal costs, and annual paperwork costs. These costs, including total annual costs and unit annual costs, are presented in Table 14.

Engineering cost analysis determined that the average pollution control investment cost per plant in Industry A is $324,615. The annual cost is $157,923, which, based on an annual plant production rate of 18,250 units, is $8.65 per unit. Plants in Industry B incur an average pollution control investment cost of $364,394 and annual compliance costs of. $234,230, or $.95 per unit of output, based on an annual plant production of 267,800 units. Plants in Industry C incur an average investment cost of $1,593,750 and, based on an annual plant production rate of 1,451,724 units, annual costs of $302,750 or 5.21 per unit of output.

The procedure that was used is as follows: these compliance costs were applied to the NPV analysis in the economic impact, section (Section E of this report) to determine the average price increase in each industry necessary to maintain pre-regulation profitability. Applying the resulting price increases to the industry's supply function determined the projected shift in the supply functions and the regulation-induced shift in outputs and prices. The results of this analysis are presented tabularly in Table 15 and graphically in Figure 3. 35/ The pre-regulation supply and demand functions were derived from the supply and demand elasticities and the equilibrium price and quantity prior to regulation. The post-regulation equilibrium price and quantity in each industry was determined by adding the required price increase to the supply function's y-intercept and deriving the new equilibrium price and quantity.

Summing the plant compliance costs at the post-regulation output level determines the private sector real resource costs for each industry. These are shown in Table 16. The pollution control investment costs are derived

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35/ The supply and demand functions presented for Industries A, B, and C are intended to characterize the range of possible relationships that may be encountered in an actual analysis. At times, studies must assume perfectly elastic supply and inelastic demand functions because industries' supply and demand relationships have not always been determined adequately. Where empirical studies have not been performed, the judgment of industry experts may have to be utilized. Where reasonable supply or demand elasticity estimates are available, the procedures presented for Industry B should be followed. Additionally, the supply shifts in this analysis are assumed to be parallel. An example of a non-parallel shift in industry supply is shown in the water case study following the present case.

Table 14. Average plant compliance cost estimates for the selected pollution control option by industry 1/

Type of cost	Industry A	Industry B	Industry C
	($/plant)		
Investment costs	$324,615	$364,394	$1,593,750
Annual costs:			
Operating & maintenance	126,923	207,730	243,750
Solid waste disposal 2/	30,000	45,000	57,000
Paperwork 3/	1,000	1,500	2,000
Total annual costs 4/	$157,923	$254,230	$302,750
Unit annual costs 5/	$8.65	$.95	$.21

1/ These cost estimates reflect the average costs that all firms in each industry will incur, i.e., the differences in costs incurred by small, medium and large plants are not indicated in the table (such differences are shown in Section E. Economic Impacts). This aggregation was necessary to perform the equilibrium analysis.

2/ Includes barrels, shipment, labor, and disposal charge at off-site landfill.

3/ Includes administrative, technical and secretarial time necessary to maintain required records.

4/ Calculated by summing the three annual costs.

5/ Calculated by dividing annual variable costs by annual production.

Table 15. Aggregate industry market data and static partial equilibrium analysis results by industry

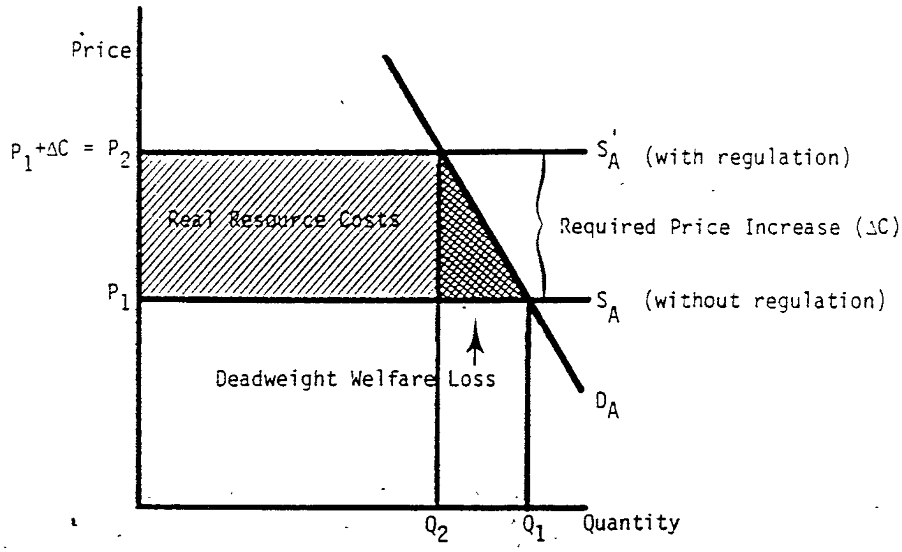
	Industry		
	A	B	C
Supply elasticity	Infinite	t.98	+1.3
Supply function (1,000 Q)	P_A=153.85	PBr-.55t.001561QB	P_C=8.7+.0032Q_C
Demand elasticity	-.48	-1.1	0
Demand function (1,000 Q)	P_A=474.37-.1351Q_A	P_B=51.64-.001391Q_B	Q_C=11,613,792
Production with regulation	2,372,500	17,678,364	11,613,792
Price without regulation	$153.85	$27.05	$29
Required price increase 1/	3.30%	1.87%	0.80%
Incremental compliance costs 2/	$5.08/unit	$.51/unit	.23/unit
Production with regulation	2,334,863	17,513,550	11,613,792
Price with regulation	$158.93	$27.28	$29.23

1 / Obtained from Section E (Economic Impacts).

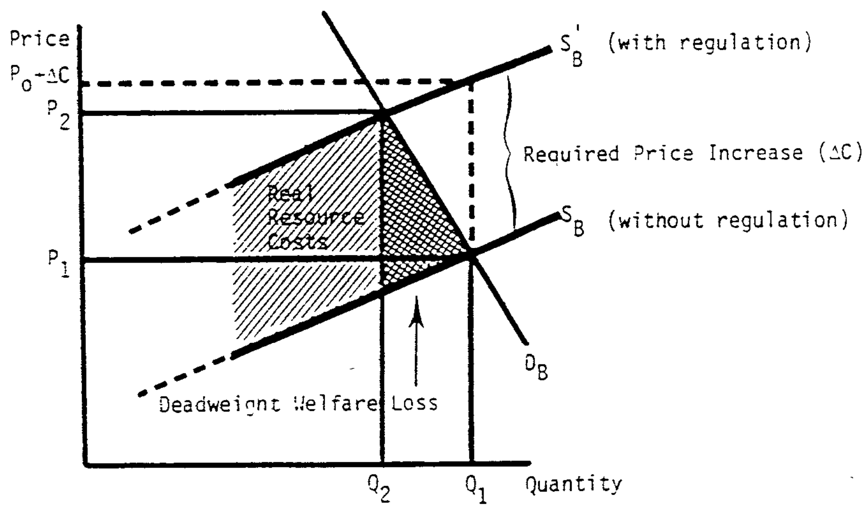
2 / Calculated by multiplying the required price increase by the price without regulation.

Figure 3. Illustration of regulation-induced supply shifts and their economic effects for Industries A, B and C

(a) Industry A



(b) Industry B



(c) Industry C

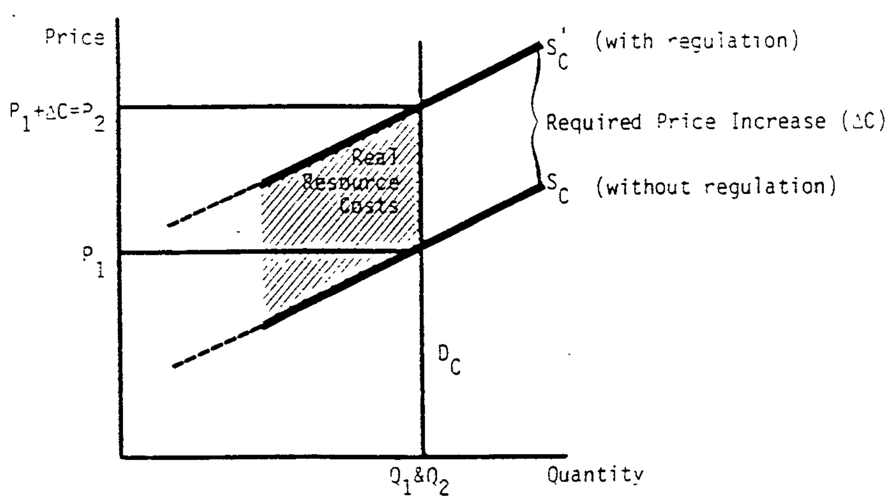


Table 16. Private sector real resource costs of the proposed Pollutant X air pollution control regulation by industry and year

	Year	Industry A	Industry B	Industry C	Total
		($million) 1/			
1	1982	0	0	0	0
2	1983	20.8	13.8	5.7	40.3
3	1984	27.9	19.6	6.7	54.2
4	1985	35.5	25.6	5.8	66.9
5	1986	21.0	17.5	2.5	41.0
6	1987	21.2	17.7	2.5	41.4
7	1988	21.4	17.8	2.6	41.8
8	1989	21.7	18.0	2.6	42.3
9	1990	21.9	18.2	2.6	42.7
10	1991	22.1	18.4	2.6	43.1
11	1992	22.3	22.3	2.7	43.5
12	1993	23.1	19.0	2.9	45.0
13	1994	23.8	19.5	3.1	46.4
14	1995	24.6	20.0	3.2	47.9
15	1996	24.8	20.2	3.3	48.3
16	1997	25.1	20.4	3.3	48.8
17	1998	25.3	20.6	3.3	49.3
18	1999	25.6	20.8	3.4	49.8
19	2000	25.8	21.0	3.4	50.3
20	2001	26.1	21.3	3.4	50.8

1/ Costs are in constant 1982 dollars.

as a function of the plants' capacities and are independent of the individual plants' production levels; therefore, such investment costs are fixed compliance costs as long as the plants are in operation. 36/ Annual costs, on the other hand, are dependent on production levels and as such, they vary with the plant's production level.

In the following analysis, the private sector real resource costs for compliance are reported on a cash flow basis; therefore, the investment costs are recorded during the year the resources are committed, i.e., the first year of the investment. Full compliance is achieved by Year 4, and for the two years prior to full compliance, it is assumed that one-third of the firms would comply per year. In addition, the calculations are based on a 1 percent growth rate in output at a stationary price.

2. Deadweight Welfare Loss

As discussed in the previous section, a given regulation may result in society foregoing consumption of some of the goods and services affected by regulation. This effect (shown in the previous section as- the decrease in each industry's output resulting from the incremental price increase) is defined as the deadweight welfare loss and represents the net reduction in consumers' and producers' surpluses which are not accounted for in the private sector real resource costs. 37/ Conceptually, this loss is a measure of consumer willingness-to-pay for the lost output less producer pre-regulation costs. In practice, this loss is measured by the area between the demand function and the industry's pre-regulation supply curve over the range of output lost due to regulation. For the present case study, the areas representing the deadweight welfare loss in each industry are shown graphically in Figure 3, and the data used to calculate the values of these areas are presented in Table 15. (Such data will not always be available to calculate actual industry deadweight welfare loss with a high degree of precision.)

The calculation for Industry A is rather straightforward since the industry supply function is horizontal. The deadweight welfare loss is composed totally of losses in consumer surplus (i.e., there is no excess profit) and is reflected in the following equation:

36/ The analysis of plant closures in the economic impact section of this case study determined that no plants will shut down as a result of the regulation; consequently, the private sector real resource costs include the total compliance investment costs for all plants. In the event a plant had been projected to close, the private sector real resource costs would have decreased by an amount equal to the plant's investment costs in addition to the decrease in annual costs resulting from the reduced output. (See the water case study following this present case for an example of this type of analysis.)

37/ The total loss in consumers' and producers' surpluses due to regulation is measured as the sum of the private sector's real resource cost and the deadweight welfare loss.

$$DWL_j = \frac{(P_{j-1} - P_j) \times (Q_{j-1} - Q_j)}{2} \qquad (20)$$

where:

DWL_j = deadweight welfare loss in year j

P = equilibrium price,

Q = equilibrium quantity, and

j = year (1, 2, 3, . . . 20)

The calculations for Industry B are more complicated because the total loss is composed of reductions in both consumer and producer surpluses. However, the calculation can be simplified and made similar to that of.. Industry A by assuming (1) that the demand and supply functions are linear, and (2) that the area representing the deadweight welfare loss is approximately equal to one half of the area bounded by the pre-regulation price, the pre-regulation price plus compliance costs, and the pre- and post-regulation outputs. Consequently, the deadweight welfare loss is calculated by multiplying the incremental compliance costs by the reduction in output and dividing the total by two.

There is no deadweight welfare loss in Industry C because no change occurs in the output level. In this case, all losses are reflected in the private real resource costs.

Estimates of the deadweight welfare losses resulting from the Pollutant X air regulation for years one to twenty are presented in Table 17. Losses in Years 2 and 3 are based on the assumption that one-third of the firms come into compliance in each year. Therefore, the loss in Year 4 represents the deadweight welfare loss resulting from 100 percent compliance.

3. Government Regulatory Costs

The costs incurred by government to implement and enforce regulations have been traditionally estimated (though not formally integrated) in regulatory analyses. These costs represent a use of resources directly related to a regulatory action and they are, therefore, a part of the cost to society that should be included in regulatory impact analyses.

The principal government costs are those related to the following activities: (1) permitting, (2) monitoring and reporting, (3) enforcement, and (4) litigation. The procedures for estimating these costs are not well defined in published literature. Various government agencies and offices have estimated these costs, however, in developing their regulatory budgets.

Table 17. Deadweight welfare loss of the proposed Pollutant X air pollution control regulation by industry and year

	Year	Industry A	Industry B	Industry C	Total
		($ thousand) 1/			
1	1982	0	0	0	0
2	1983	31.9	14.0	0	45.9
3	1984	63.7	28.0	0	91.8
4	1985	95.6	42.0	0	137.6
5	1986	95.6	42.0		137.6
6	1987	95.6	42.0	0	137.6
7	1988	95.6	42.0	0	137.6
8	1989	95.6	42.0	0	137.6
9	1990	95.6	42.0	0	137.6
10	1991	95.6	42.0	0	137.6
11	1992	95.6	42.0	0	137.6
12	1993	95.6	42.0	0	137.6
13	1994	95.6	42.0	0	137.6
14	1995	95.6	42.0	0	137.6
15	1996	95.6	42.0	0	137.6
16	1997	95.6	42.0	0	137.6
17	1998	95.6	42.0	0	137.6
18	1999	95.6	42.0	0	137.6
19	2000	95.6	42.0	0	137.6
20	2001	95.6	42.0	0	137.6

1/ Costs are in constant 1982 dollars.

Accurately estimating government costs would also require allocating the regulatory responsibilities and costs among federal, state and local government levels. The required resources at each of these levels, is dependent on the specific regulatory action and the projected roles of each level of government.

For the purpose of this case study, a hypothetical summary of government costs for one year is shown in Table 18, and the hypothetical government costs for the 20-year time horizon are shown in Table 19. Specific EPA procedures for estimating the types of costs presented are often unavailable. In their absence, the "best judgment" of Agency budget planners may be utilized.

Some of the functions that should be considered when estimating each of the principal types of government regulatory costs are the following:

Type of Cost	Factors Affecting Cost
• Permitting	• Staff time (administrative, technical and clerical) • Computer time • Number of permits processed
• Monitoring and reporting	• Number of sites • Type of monitoring • Reporting burden and processing time
• Enforcement	• Staff time • Number of sites • Degree of complexity of regulation • Level of enforcement
• Litigation	• Case load (projected) • Level of enforcement

Each type of cost should be estimated as a function of variables that are related directly to the projected growth in emissions and compliance assumptions.

4. Adjustment Costs

One of the possible consequences of a regulatory action is that reductions in output induced by the regulation will displace resources through such effects as plant closures and job losses. Although theoretically these resources will be re-employed in the long run and society will incur only temporary costs, realistically speaking, market imperfections (i.e., variations from the theoretical assumptions of perfect competition) may prevent re-employment of some resources even in the long run. Therefore, adjustment costs should include: (1) the value of the resources temporarily

Table 18. Government regulatory costs 1/ of the proposed Pollutant x air pollution control regulation in Year Two

Government Activity	Government Level			Total
	Federal	State	Local	
	($)			
Permitting	100,000	100,000	---	200,000
Monitoring	10,000	70,000	20,000	100,000
Enforcement	12,500	35,000	2,500	50,000
Litigation	30,000	15,000	5,000	50,000
Total	152,500	220,000	27,500	400,000

1/ Costs are in constant 1982 dollars.

Table 19. Government regulatory cost of the proposed Pollutant X air pollution control regulation by year

Year		Total Cost 1/
		($ thousand)
1	1982	0
2	1983	400.0
3	1984	550.0
4	1985	700.0
5	1986	502.0
6	1987	502.0
7	1988	502.0
8	1989	442.0
9	1990	432.0
10	1991	324.0
11	1992	314.0
12	1993	404.0
13	1994	329.0
14	1995	319.0
15	1996	211.0
16	1997	201.0
17	1998	291.0
18	1999	256.0
19	2000	246.0
20	2001	138.0

1/ Costs are in constant 1982 dollars.

unemployed, (2) the costs of relocating the displaced resources, (3) the administrative costs for transfer payment programs, (4) the welfare loss or gain resulting from the redistribution of resources, and (5) the value of resources permanently unemployed.

Generally, estimates of such costs are based upon the type of distributional impacts assessed in the economic impact section of this report; however, it is not always known whether or not displaced resources will become unemployed or underemployed in the long run. When such quantifiable data are unavailable, such costs should be discussed qualitatively.

The economic impact section of this case study indicated that no plant closures would occur and that the resultant industry unemployment would be minimal. Therefore, in this case, no adjustment costs occur. For an example of the procedures followed when adjustment costs do occur as a result of regulatory compliance, see the water pollution control regulation case study in the latter section of this Appendix.

E. Economic Impacts

This section of the RIA addresses the equity impacts of the regulation in question in contrast to the efficiency impacts of the regulation that were considered in the preceding benefits and costs analyses. In general, any regulation that results in higher production-related costs (e.g., those related to the addition of pollution abatement technology by manufacturing plants) without comparably improving the affected plants' operating efficiencies will show measurable economic impacts. Such equity impacts measure the proportionate distribution of the regulatory-induced costs and benefits among consumers, producers, and government. In considering such impacts, the Agency's principal emphasis should include the following measures of effects: financial, price, production, employment, industry profitability, and community effects. Additionally, when applicable, the balance of trade, energy use, productivity, and intergenerational effects should also be assessed.

Ideally, the economic impacts of regulations would be determined by estimating, individually and -collectively, the compliance behavior of plants and the associated impacts of their pollution abatement practices. Since such a plant-by-plant approach is seldom feasible, a. frequently used alternative is to estimate the economic profiles for representative or model plants (e.g., by process, size and/or age) and will use such profiles to estimate applicable financial impacts with and without the proposed regulation. These microeconomic effects may subsequently be extended to estimate macroeconomic effects and industry-wide behavior, including those related to price and production effects.

The aggregate industry characteristics and pollution control costs estimated for this case study were summarized in Section D. The economic impacts summarized in the present section apply to representative firms (model plants) within each of the affected industries and reflect their expected market behaviors with the proposed regulation.

1. Financial Effects

The economic viability of firms both with and without pollution controls is reflected through various financial indicators such as the following:

- After-tax return on sales
- After-tax return on total assets
- Annual cash flow
- Net present value.

Analysts, using model plant financial profiles and appropriate assumptions for inflation, depreciation, and reinvestment, can measure such indicators for a designated period of analysis, e.g., 20 years. Then, to assess the financial effects of regulatory control costs, such measures should be made for a (1) baseline case (without the regulation) and (2) for each regulatory option. The differences in the financial indicators between the baseline and each regulatory option will then show the key financial effects of the regulation. Year-to-year variation in the financial measures will occur when yearly costs, revenues, reinvestments, and pollution control expenditures are forecast, but these variations may be compensated for by computing the average measures over the period of analysis. Finally, the financial viability of the model firms at the end of the period of analysis should be estimated in order to reflect the long-term effects of regulation as opposed to the intermediate or short-term effects that may occur because of uneven pollution control costs or reinvestments.

An illustration of the types of financial data that may be developed for model plants is shown in Table 20. Three model plant sizes are shown for both Industry A and Industry B; two model plants--reflecting different processes--are shown for the Industry C. All model plants' financial profiles are illustrated under baseline conditions. Each of the models is economically viable in the indicated base period (Year 0); for example, the after-tax returns on sales are all positive, ranging from 4.4 to 4.9 per cent in Industry A, from 4.2 to 4.5 percent in Industry B,and from 6.3 to. 6.5 percent in Industry C. Other financial characteristics shown in Table 20 include revenues, costs, pre-tax income, and cash flows. To aid in comparing these various financial profiles within an industry, each financial measure is also expressed as a percent of the estimated annual revenue (sales).

Additional financial profile data are required to compute both the after-tax return on total assets and the net present value of projected operations. In general, the following types of financial data are preferred for these analyses:

Total assets = Fixed assets + Current assets

Net working capital = Current assets - Current liabilities

Total invested capital = Fixed assets + Net working capital

Salvage value = Net working capital + Fixed assets times a salvage factor.

These types of data change year-by-year for an on-going plant; hence, a generally recommended analytical approach is to simulate (with a cash flow analysis) the operation of each model plant over the study's period of analysis. This dynamic simulation procedure can be conducted for each model plant both for the without-regulation case (baseline) and the with regulation case. Net present value analysis may then be conducted to compare the two cases in order to assess the financial and economic effects of regulatory compliance costs.

Selected financial effects of the proposed pollution controls are illustrated below for each of the model plant sizes in Industries A, B and C. Table 21 summarizes the investment and the annual operating and

Table 20. Financial profiles for representative plants in hypothetical Industries A,B and C, baseline (Year 0) (1982 constant dollars)

Item	Industry A						Industry B						Industry C			
	Small		Medium		Large		Small		Medium		Large		Process 1		Process 2	
	$1,000	%	$1,000	%	$1,000	%	$1,000	%	$1,000	%	$1,000	%	$1,000	%	$1,000	%
REVENUE (sales)	1,500	100.0	3,500	100.0	5,000	100.0	3,300	100.0	7,500	100.0	12.400	100.0	39.500	100.0	46,750	100.0
COST																
Raw Material	720	40.0	1,650	47.2	2,300	46.0	1,500	45.5	3,375	45.0	5,530	44.6	18,950	48.0	23,850	51.0
Labor	300	20.0	680	19.4	950	19.0	460	13.9	1,010	13.5	1,610	13.0	7,900	20.0	8,400	18.0
Other 1/	260	17.3	665	19.0	950	19.0	890	27.0	2,215	29.5	3,610	29.1	6,650	16.8	6,550	14.0
TOTAL	1,280	85.3	2,995	85.6	4,200	84.0	2,850	86.4	6,600	88.0	10,750	86.7	33,500	84.8	38,800	83.0
GROSS EARNINGS	220	14.7	505	14.4	800	16.0	450	13.6	900	12.0	1,650	13.3	6,000	15.2	7,950	17.0
LESS																
Depreciation	70	4.7	150	4.3	225	4.5	150	4.5	250	3.3	500	4.0	500	1.3	750	1.6
Interest	50	3.3	105	3.0	180	3.6	60	1.8	100	1.3	200	1.6	900	2.3	1,575	3.4
PRE-TAX INCOME	100	6.7	250	7.1	395	7.9	240	7.3	550	7.3	950	7.7	4,600	11.6	5,625	12.0
INCOME TAX	27	1.8	96	2.7	162	3.2	91	2.8	234	3.1	418	3.4	2,097	5.3	2,568	5.5
AFTER-TAX INCOME.	73	4.9	154	4.4	233	4.7	149	4.5	316	4.2	532	4.3	2,503	6.3	3,057	6.5
CASH FLOW	143	9.5	304	8.7	458	9.2	299	9.1	566	2.5	1,150	9.3	3,033	7.6	3,807	8.1

1/ Other includes insurance, taxes (non-income), selling, administrative, and other operating and Maintenance costs.

Table 21. Summary of model plant pollution control costs for Industries A, B and C

Industry/Model	Number of plants	Pollution control costs 1/ Investment	O&M
		----------($000)----------	
Industry A			
Small	60	200	80
Medium	50	400	150
Large	20	510	210
Industry B			
Small	25	250	130
Medium	23	420	220
Large	18	730	300
Industry C			
Process 1	5	1,500	225
Process 2	3	1,750	275

1/ Costs are in 1982 constant dollars.

maintenance costs for each industry's model plants in contrast to the aggregate or average industry costs presented in Section D above. The financial effects on each model were based upon a discounted cash flow analysis for a simulated 20-year operating period. A sensitivity analysis based upon either plus or minus 10 percent changes in pollution control investment and operating and maintenance costs is also illustrated.

a. Return on sales

The model plants' projected 20-year average returns on sales (ROS) with and without the proposed regulation are shown in Table 22. For example, Industry A's small plant is projected to have an after-tax ROS of 3.3 percent with pollution controls compared to its 6.6 percent without controls. Results for the other model plants are shown in the table.

Assuming no price increases, all model plants will show decreasing ROS results following pollution controls; however, new market equilibrium prices may partially or fully off-set this initial ROS effect. Because no price changes are included in this portion of the analysis these ROS effects are worst-case estimates for each of the model plants;

b. Return on total assets

Because total assets are higher with pollution controls and revenues (prices) are initially held constant, the return on total assets (ROTA) will also decrease in the pollution control as opposed to the baseline case. The ROTA financial effects of the proposed regulation for each of the model plants are also shown in Table 22.

For example, the Industry A small model plant has an estimated 12.4 percent ROTA with pollution controls compared to 23.6 percent in the baseline case. The estimated ROTA varies during the period of analysis and the values shown are those 20-year averages that reflect the general, long-term financial effect of the proposed regulation. (Although total assets are not shown here, they may be derived for each model plant from the reported sales and the ROTA estimates data.)

c. Annual cash flows

The annual cash flow is equal to the after-tax profits (net income) plus depreciation. Positive cash flows were forecast for each of the models throughout the period of analysis. A comparison of the 20th-year cash flow estimates, with and without the pollution controls, for each of the model plants generally indicates this financial effect. These cash flow estimates are summarized in Table 22. For example, the 20th-year cash flows for the Industry A small model are estimated as $461,000 in the baseline case and as $302,000 under the proposed requlation. Similar cash flow estimates for all of this study's model plants are included in the table.

Table 22. Selected model plant financial effects of the proposed pollution controls compared to baseline conditions for Industries A, B and C, 20-year discounted cash flow analysis 1/

Financial effect	Industry A			Industry B			Industry C	
	Small	Medium	Large	Small	Medium	Large	Process 1	Process 2
Return on sales (%)								
• Baseline	6.6	6.2	6.7	6.3	5.5	6.0	8.7	12.2
• With controls	3.3	3.7	4.3	4.1	3.9	4.6	8.3	11.8
Return on total assets (%)								
• Baseline	23.6	22.4	23.9	31.4	33.7	31.7	44.2	65.5
• With controls	12.4	13.4	15.4	20.1	23.4	23.9	41.6	62.3
Annual cash flow ($000)								
• Baseline	461	1,039	1,624	942	1,873	3,411	14,527	23,910
• With controls	302	740	1,207	684	1,437	2,814	14,082	23,367
Net present value ($000)								
• Baseline	601	1,180	2,255	1,071	2,683	2,927	27,535	54,623
• With controls	94	231	927	249	1,292	1,029	26,338	53,147

1/ Results displayed represent a "worst case" assumption (that no costs are passed through to prices); moreover, results are 20-year averages, i.e., year-by-year DCF results are not displayed.

d. Net present value

The sum of the present values of the cash flows (after-tax income plus depreciation) over the period of analysis (including the salvage value of the plant in the final period) indicates the net present value (NPV) of the plant to the equity holders in excess of (or below) the firm's cost of capital, i.e., the discount rate.

A positive NPV for the period of analysis indicates that the equity holders are earning a return which is greater than the model's cost of capital; conversely, a negative-NPV would indicate that the equity holders are earning less than the cost of capital. In this latter case, the equity holders would presumably be better off liquidating the firm, realizing the salvage value in cash, and reinvesting it in other opportunities that return at least the firm's (or industry's) cost of capital.

NPV's may be computed for each year of an analysis; the 20th-year NPV's indicate whether the plant will maintain its economic viability in the relatively long-run. Using a cost of capital (after-tax discount rate) of. 11.0 percent, the 20th year NPV's for each of the model plants are as shown in Table 22. Again, for the Industry A small plant, the NPV's with and without the proposed regulation are $94,000 and $601,000, respectively. The positive NPV in the pollution control case indicates that the model is viable and that it will have returns in excess of the estimated cost of capital.

2. Price Effects

An initial indicator of the expected price effect of higher pollution control costs is the required price increase by a firm to maintain its profitability at the pre-control level. To estimate the ability of firms to fully pass through such required price increases involves a market analysis of current and future supply and demand conditions. (Illustrative summary analyses for Industries A, B and C were presented in Section D.)

If discounted cash flow procedures are used to estimate present values of pollution control costs (i.e., investment plus operating costs less tax savings), then the following formula will approximate the required price increase (RPI):

$$RPI = \frac{(PVC)(100)}{(1-t)(PVR)}$$

where

PVC = present value of pollution control costs

PVR = present value of gross revenue beginning in the year that pollution controls are imposed

t = average tax rate.

Each model plant will have a different required price increase level to maintain profitability, and the ability of firms to realize higher prices is dependent upon industry supply and demand price elasticities and upon competitive market conditions.

For each of the present study's model plants, the following required price increases were estimated based upon the above formula. As shown, ranges of required price increases were also determined to illustrate the sensitivity of this measure to alternate pollution control cost levels, i.e., ±10 percent from the original estimates.

Industry/Model	Required price increase with regulation (%)*		
	-10% PCC	Target PCC	+10% PCC
Industry A:			
Small	3.5	3.8	4.2
Medium	2.9	3.2	3.5
Large	2.7	3.0	3.3
Industry B:			
Small	2.2	2.5	'2.7
Medium	1.6	1.8	2.0
Large	1.5	1.7	1.9
Industry C			
Process 1	0.7	0.8	0.9
Process 2	0.7	0.8	0.9

* Pollution control costs (investment and operating and maintenance) were varied from their initial levels (target PCC) by plus and minus 10 percent.

While these required price increases would permit each model plant to maintain its pre-control profitability level, various economic constraints (e.g., availability of substitutes, international competition) may limit the pass-through of the pollution control costs to consumers. Also, the large model plants, with relatively lower required price increases, may limit their price increases to maintain or enhance their competitive position vis-a-vis other plants or other sources of competition. Furthermore, as the marginal costs of production increase at individual plant levels, aggregate supply for the industry will shift-upward. The resultant macroeconomic effect will be a new market equilibrium resulting from the aggregate supply shift--a new, lower output level (quantity demanded) and a downward price adjustment that are both dependent upon demand and supply price elasticities.

Additional industry-level analysis (as summarized in Section D) predicted that the market price-effects of the proposed regulation would be the following:

Industry A -- 3.3% price increase
Industry B -- 0.9% price increase
Industry C -- 0.8% price increase

These price increases will at least partially offset the higher costs of production resulting from the additive costs of pollution controls. The economic viability of the model plants can also be re-assessed, if necessary, to measure the effects of these predicted price increases rather than the analysis merely considering only the worst-case effects without price increases. However, because the NPV analysis indicated that even in the absence of price increases no plant closures were likely in any of the three industries, a further economic viability assessment is not mandatory (though it is desirable). The net price effect on each model would be the difference between the previously required price increase for each industry's model plants and the above predicted industry-level price increases.

3. Production Effects

In order to assess the effects of regulatory costs on production, total industry production should be estimated annually for the period of analysis--again under baseline and regulatory conditions. Historical data may often be utilized to indicate production trend relationships and to assess cyclical or other patterns of growth, and industrial outlook reports and a specific industry's growth prospects relative to aggregate indicators, e.g., GNP forecasts, can be utilized to project these relationships for model firms vis-a-vis the industry and the general economy. In some industries, baseline plant closures can be expected regardless of the costs of added regulatory requirements; consequently, such expectations should be included in the baseline.

Production levels for an industry may increase while, concurrently, plant closures occur if other existing firms expand production or new plants are built. Such estimates must be taken into account to simulate model plant operation over the period of analysis, for any factors that change expected utilization rates will affect unit costs and total sales revenues. Reasons for plant closures unrelated to the imposition of regulations are numerous and include the following:

- increased production of substitutes,
- increased international competition,
- higher per-unit costs of production in some plants, e.g., uneconomic small plant costs,
- obsolescence of process technology,
- lower per-unit profit, and
- owner retirement.

Careful assessments of plant closures under both baseline conditions and under the proposed regulation are needed to estimate the net effect of regulation on plant closures and production.

For this case study, no plant closures are forecast, but each industry is expected to experience a market equilibrium adjustment, i.e., an upward shift in the industry's supply function from the pre-regulation level with a consequent change in the equilibrium price and quantity. Normally, the new price will be hiqher and the quantity demanded (for a given time period) will be lower. Both supply and demand price elasticities are critical for estimating these effects.

As previously illustrated in Section D, the following relative price and quantity market equilibrium adjustments were forecast:

Industry	Supply price elasticity	Demand price elasticity	Price effect	Quantity effect
A	Infinite	-.48	+3.3%	-1.6%
B	+.98	-1.10	+0.9%	-0.9%
C	+1.30	0	+0.84;	0

The production effects of a proposed regulation are the indicated relative reductions in quantities demanded at the‘projected higher prices. These aggregate adjustments are to be distributed among all plants in each respective industry, although precise estimates of such distributional effects could not be provided in this analysis. Presumably, the plants with comparatively high marginal costs will reduce output relatively more in the short-run, although insufficient data are available to simulate each model plant's marginal cost relationships.

4. Employment Effects

Both favorable and unfavorable employment effects may occur when pollution abatement regulations are imposed. Favorable effects include short-term construction employment to install pollution-related equipment or structures and the additional personnel that may be hired to operate and maintain the pollution control facilities. In contrast, if a net increase in plant closures (above baseline) is attributable to she regulation, plant-related employment losses will result. Estimates should be made of such employment losses and of alternative employment opportunities requiring comparable skill levels. A minimum expected effect is that short-term transition costs will be incurred by employees affected by production curtailments or plant closings.

Where a more extensive assessment of employment impacts is necessary, an estimate of secondary employment effects must be made. Because employment by suppliers of raw materials and by service industries can be affected if substantial job dislocation occurs in an affected area, all such employment should-be projected. (Employment effects, both direct and indirect, are also instrumental in assessing community effects as below.) Furthermore, employment effects over time must be considered in determining ultimate regulatory costs to society.

Two types of positive employment effects are projected for this case study. First, short-term construction employment of 338, 192 and 102 work years for Industries A, B and C, respectively, are projected for installing the pollution controls in existing and new plants. Second, additional long-term personnel are required to operate and maintain the pollution control equipment -- 150 in Industry A (1 employee in each small and medium, and 2 in each large plant), 125 in Industry B (1 employee in each small, 2 in each medium and 3 in each large plant), and 32 in Industry C (4 employees in each plant). No employment losses are projected to result from the slightly lower production levels in the short-term because long-term growth in each of the industries will relatively quickly offset the projected production losses.

Secondary positive employment effects are expected to be negligible because purchases of raw materials and other inputs will not change markedly. Also, the levels of purchases of pollution control equipment by these industries are assumed to be available through existing sources without requiring an expansion in the pollution control equipment industry. Finally, although minor increase's in demand will occur for substitute products from industries that do not generation Pollutant X, no significant quantity effects on the demand for Industries A, B, and C's products are projected.

5. Community Effects

The ability to adequately assess the community effects of regulatory costs is highly dependent upon the analyst's knowledge of the community settings of the actual plants that will be affected by the proposed regulation. Any adverse or favorable effects on particular communities cannot be deduced from model plant analysis with a high degree of confidence. For example, should a small-size model plant appear nonviable with pollution controls, further analysis should be conducted regarding the communities in which such plants are located. In general, a small plant closure in a rural setting may have widespread community effects; the closure of a similar plant in a large urban area may result in relatively minor community effects following the transition of employees to other employment opportunities --an exception could be an urban area already suffering high unemployment, as is the case in some Northeastern cities.

For the case study, no consequential community effects are forecast.

6. Trade Effects

Balance of trade effects are first dependent upon the relative importance of the affected industries' products in international import and export trade. When such trade is sizeable, the competitive price effects of the pollution control costs should be carefully analyzed. For example, the probable effects of control costs on exporting firms if their economies of size are important should be examined, for firms involved in international trade may experience less than average price effects because of size or other operating characteristics. Similarly, a larger share of the product market may be gained by importers unless domestic firms remain competitive.

Frequently, prospective shifts in the balance of trade are theoretically desirable in terms of efficiency. However, if (and when) a comparative advantage in domestic production were to shift to foreign producers because of national differences in pollution abatement regulation and costs, this is likely to be an important public policy concern.

For this particular case study, the balance of trade effects are assumed to be negligible. When applicable, however, a comprehensive analysis of market supplies, by source, is critical. When, for instance, a sizeable portion of an industry's supply is imported, potential price increases from pollution controls may be restricted to prevent a greater market share accruing to importers. Of course, if exports are substantial, these sales may not be sustainable under the price increases required for pollution controls. Generally speaking, a market supply-demand analysis is required of both domestic and international markets to ascertain the probable balance of trade effects.

7. Other Effects

All other major effects that result directly or indirectly from regulatory actions should also be assessed; energy, productivity, and intergenerational effects are of particular concern. Energy effects are a concern if pollution controls directly or indirectly require that substantially increased energy supplies be utilized per unit of output. Such increases would both offset some of the pollution abatement benefits from controls and would contribute to higher demand and prices for energy in all uses. This case study assumed thatt the energy effects of the proposed regulation are negligible.

Productivity effects are a concern if regulation substantially increases the cost per unit of output either directly or indirectly through restrictions on the use of preferred technological processes. In either case the choice of regulatory options will be questioned. This case study assumed that the firms' productivity was unaffected by the proposed regulation.

Intergenerational effects should be described and qualitatively assessed even though acceptable methods of quantifying these effects may be presently unknown. Various types of "irreversible" pollution-related effects may occur--both as damages (e.g., to fragile environments and ecosystems) and as barriers to industry entry caused by a too stringent regulation. Various other health, aesthetic, material and ecological effects may be long-term and intergenerational. Although such effects may not be quantifiable for a relatively short (e.g., 20-year) period of analysis, they should be described so that they may be qualitatively considered in the economic impact analysis. No irreversible effects were found to exist in the case study.

F. Net Benefits Timestreams and Sensitivity Analysis

1. Net Social Benefits

The total social benefits and total social costs streams for the 20-year period of analysis as determined in Sections C and D are the basis for estimating net social benefits. For each period (year), the net social benefit is derived as follows:

$$NSB_t = TSB_t - TSC_t$$

where

NSB_t = Net Social Benefits

TSB_t = Total Social Benefits

TSC_t = Total Social Costs

t = year t

A summary of each of these variables for the case study is presented in Table 23. As shown, the NSB's are negative in the earlier years, but they are positive in subsequent years.

In order to judge whether the net social benefits stream for the proposed regulation is acceptable to society, the present values of the social benefits and social costs (or just the Net Social Benefits) may be calculated using a "social discount rate." Using a rate of 10 percent, as specified by OMB, the present value of the Net Social Benefits for the proposed Pollutant X air pollution control regulation is 583.7 million.

Because this NSB present value is positive, the proposed regulation achieves benefits that exceed costs (including the time-value of costs and benefits to society). Each alternative should be examined to determine whether greater NSB's can be achieved.

Another component of the net social benefit that is not "valued" in the above analysis is the benefits accruing to human health, particularly, the projected number of lives saved by the regulation. In Section C and as discussed previously, an estimated 1,269 deaths will be avoided because of the proposed regulation. Should there have been "excess costs" above the expected quantifiable benefits, an analysis could show the average excess cost per death avoided as a further gauge in evaluating the regulation.

2. Sensitivity Analysis

The discount rate used in computing present values may be critical in determining whether the present value of calculated NSB's is positive or negative. This condition is true whenever an uneven distribution of benefits and costs occurs so that NSB's are both negative and positive during the period of analysis.

A summary of the present values of the total social benefits, total social costs, and the net social benefits for the proposed regulation using alternative discount rates is the following:

	Present Value*			
	6%	8%	10%	12%
	---------millions of dollars--------			
Social Benefits	644.8	532.2	444.7	375.9
Social Costs	499.3	421.9	361.0	312.5
Net Social Benefits	145.5	110.3	83.7	63.4

* Before calculating present values, the costs and benefits were expressed in constant 1982 dollars.

As indicated, the present values are positive; they do decrease, however, as the discount rate is increased from 6 percent to 12 percent. At a discount rate of approximately 30 percent, the present value of the net social benefits would equal zero.

Throughout both the benefits and costs analyses (see Sections C and D), ranges in the study's estimates were developed to reflect uncertainties in available data or in the implementable analytic procedures. Each component benefit and cost estimate may vary by differing degrees from the study's primary or target estimate. However, these ranges of estimates may be aggregated in the same manner as the primary estimates, yielding ranges in the study's total benefits and total costs as summarized in Table 23.

Present values of the net social benefits for the proposed Pollutant X air pollution control regulation will also vary when either the underlying benefits or costs change, and an important assessment is to show the sensitivity of net social benefits relative to changes in either the benefits or the costs. Table 24 illustrates this sensitivity for the following two sets of conditions:

1. Maintain Total Social Benefits at the primary-estimate level while varying the Total Social Costs from their low to high levels. (Discount rate equal to 10 percent.)

Table 23. Undiscounted total social benefits, total social costs and net social benefits for the proposed Pollutant X air pollution control, regulation by year

Year	Total social benefits 1/ estimate	Total social benefits 1/ Range	Total social costs 2/ Estimate	Total social costs 2/ Range	Net social benefits 3/ Estimate	Net social benefits 3/ Range
	-----millions of dollars-----					
1 1982	0	0	0	0	0	
2 1983	19.6	14.3-24.3	40.8	36.7-44.8	(21.2) 4/	(22.4)-(20.46)
3 1984	37.5	27.7-46.0	54.8	49.4-60.2	(17.3)	(21.7)-(14.2)
4 1985	57.2	42.8-71.1	67.7	60.9-74.4	(10.5)	(18.1)-(3.3)
5 1986	59.3	44.2-73.8	41.7	37.5-45.9	17.6	6.7-27.9
6 1987	60.3	45.2-75.6	42.1	37.8-46.3	18.2	7.4-29.3
7 1988	61.8	46.2-77.4	42.5	38.2-46.7	19.3	8.0-30.7
8 1989	63.2	47.3-79.1	42.8	38.5-47.0	20.4	8.8-32.1
9 1990	64.8	48.3-80.9	43.2	38.7-47.4	21.6	9.6-33.5
10 1991	66.3	49.3-82.7	43.6	39.2-47.8	22.7	10.1-34.9
11 1992	68.0	50.5-84.8	44.0	40.1-48.9	23.2	10.4-35.9
12 1993	69.6	51.8-86.9	45.5	41.0-50.0	24.1	10.8-36.9
13 1994	71.3	53.0-89.1	46.9	42.0-51.1	24.4	11.0-38.0
14 1995	73.0	54.3-91.2	48.3	42.9-52.2	24.7	11.4-39.0
15 1996	74.6	55.5-93.3	48.7	43.8-53.3	25.9	11.7-40.0
16 1997	76.4	56.7-95.6	49.1	44.7-53.9	27.3	12.0-41.7
17 1998	78.3	57.8-97.8	49.7	45.6-54.5	28.6	12.2-43.3
18 1999	80.0	59.0-100.1	50.2	46.6-55.1	29.8	12.4-45.0
19 2000	81.7	60.1-102.3	50.7	47.5-55.7	31.0	12.6-46.6
20 2001	83.6	61.3-104.6	51.1	46.0-56.0	32.5	15.3-48.6

1/ Inflated to 1982 dollars using the GNP Implicit Price Deflator.
2/ In 1982 dollars.
3/ Total social benefits minus total social costs.
4/ Numbers in parenthesis are negative.

2. Maintain Total Social Costs at the primary-estimate level while varying the Total Social Benefits from their low to high levels. (Discount rate equal to 10 percent.)

For example, if the high cost estimates are experienced while benefits remain at the primary-estimate level, the net social benefits will equal $48.2 million versus the estimated $83.7 million when both benefits and costs are at their primary-estimate levels. Table 24 summarizes the other cases included in the above sets of conditions.

Two additional cases are of general interest: namely, the "best" and the "worst" cases as reflected by the corresponding net social benefits estimates. The "best" case is represented by high benefits and low costs, whereas the "worst" case is represented by low benefits and high costs. The present values of the net social benefits (at the 10 percent discount rate) for these two extreme cases are the following:

Case	Present Value	Comment
"Best"	228.8	High benefits; low costs
"Worst"	-65.8	Low benefits; high costs

All other benefit-cost combinations within the ranges estimated will have present values between these extremes using the 10 percent discount rate.

Table 24. Present values of net social benefits for selected ranges in total social costs and total social benefits for the proposed Pollutant X air pollution control regulation

Sensitivity conditions	Net social benefits present value 1/
	($ million)
Social Benefits-Constant 2/	
Social Costs - High	48.2
Social Costs - Moderate	83.7
Social Costs - Low	119.0
Social,Costs - Constant 2/	
Social Benefits - High	193.6
Social Benefits - Moderate	83.7
Social Benefits - Low	-30.3

1/ All present values of net social benefits were calculated using a 10 percent discount rate.

2/ Social benefits (and social costs) are held constant at the primary-estimate (moderate) level while social costs (social benefits) range from high to low as defined in Table 23.

G. Cost-Effectiveness

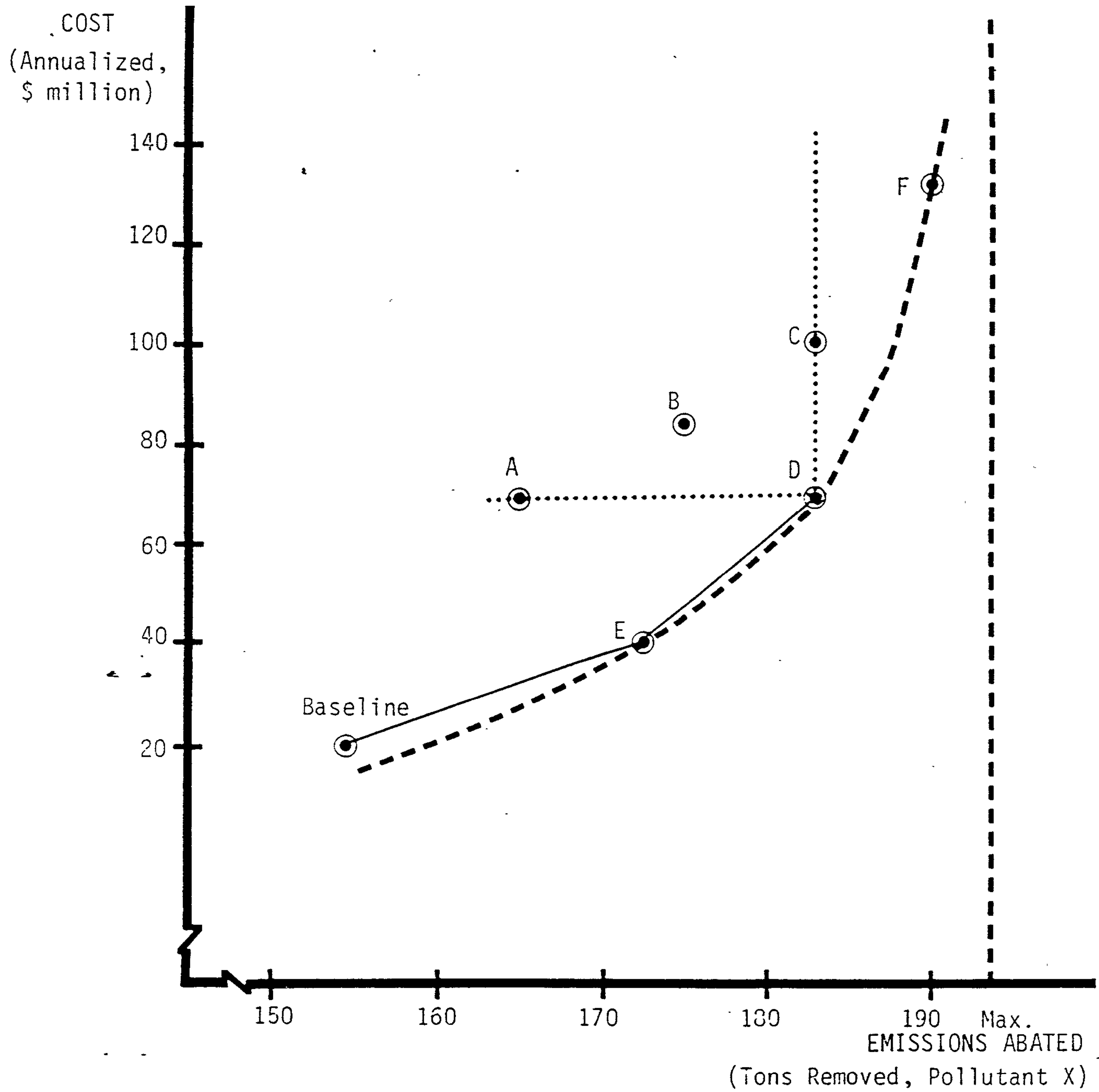
Cost-effectiveness (C/E) analysis is an important analytical procedure for evaluating management options that have a common objective (e.g., Pollutant X abatement) and that have costs expressible in comparable units. (e.g., annualized dollars). Although cost-effectiveness analysis is not fully standardized, the EPA's Office of Air Quality Planning and Standards has included C/E analysis guidelines in its report: "Operating Procedures and Analytical Methods Manuals" (September 1981). Analysts generally agree on the concepts of C/E analysis; differences exist, however, in their use of terminology and in their interpretation of discrete (vs. continuous) empirical results that measure average or incremental cost-effectiveness rather than marginal cost-effectiveness as is theoretically preferred.

Cost-effectiveness (C/E) is defined for this study as the annualized cost per unit of Pollutant X abated or removed. Also, as is theoretically expected, when the degree of abatement (stringency of control) increases, the cost per unit of abatement increases at an increasing rate, i.e., the marginal C/E increases as the stringency level 'approaches the maximum.

Often, several technological and managerial options exist for achieving either a pre-established abatement level or for controlling pollutants given a cost constraint. When neither the effectiveness-level (abatement) nor the cost is restricted, the role of C/E analysis becomes apparent--to identify the least-cost set of alternatives (management options) over a range of effectiveness-levels. (Note that further economic analysis, e.g., benefit-cost analysis, is required to estimate the preferred effectiveness level from the least-cost C/E set). C/E analysis will show that those regulatory options which are least-cost alternatives (and on the least-cost envelope curve depicted in Figure 4) are preferable to those which contain alternatives that are not in the least-cost set. Hence, various regulatory alternatives may be appropriately excluded from additional study based upon C/E analysis results, and the remaining least-cost set of options may be further analyzed to estimate the socially optimum level of control.

Figure 4 depicts both the C/E analysis concepts defined in the preceding discussion and the present study's hypothetical set of regulatory options --namely, Alternatives A to F. In Figure 4, the vertical axis represents the annualized total cost for Pollutant X abatement, and the horizontal axis shows the degree of abatement (shown as total tons abated). The dashed curve is the theoretically-deduced marginal cost-effectiveness curve. This curve is seldom empirically derivable because underlying technological options are nearly always discrete and finite. However, regulatory Alternatives D, E and F represent the "least cost envelope curve" because each of their cost and emissions abated values depicted in Figure 4 show "dominance" of either less cost or greater effectiveness vis-a-vis all other alternatives. Alternatives A, B and C are said to be "inferior" because they are dominated by one or more of the least-cost C/E set--D, E or F, as is explained further below.

Figure 4. Cost-effectiveness of the proposed regulatory alternative (D) compared to other selected alternatives



Regulatory Alternative D was the proposed option in this study for which a benefit-cost analysis was illustrated in the preceding sections. Using C/E analysis only, Alternative D is shown in Figure 4 to be preferable to Alternatives A, B and C: the cost and emissions abated values for these alternatives are as follows:

Alternative	Annualized cost ($million)	Emissions abated (1,000 tons)
A	71.3	165.0
B	86.0	175.0
C	103.0	183.2
D	71.3	183.2

Alternative D is said to "dominate"--to be more cost-effective than is each of the other alternatives because its cost is less than or equal to and its amount of emissions abated is greater than or equal to those of the other alternatives. Compared to Alternative A, D's total annualized cost is equivalent, but its abatement effect is greater. Alternative B has both a higher cost and a less effective abatement level. Alternative C has the same abatement effect as D, but C is more costly. In such situations, then, the least-cost, most effective alternative can be isolated. No further analysis is necessary in choosing the preferred alternative, i.e., Alternative D, from this subset.

As Figure 4 shows, another graphic indicator of the "dominance" of an alternative is the position that its cost and abatement effect values have on the graph--those located above or left of those of any given alternative are inferior values. The dotted lines from Alternative D in Figure 4 illustrate this concept. (Note also that Alternative A is inferior to Alternative E using this criterion.) Cost-effectiveness ratios may be computed to further indicate the preferred dominant alternative. For example, the C/E ratio for D is $389 per ton, whereas those for A, B and C are $432, $491 and $562 per ton, respectively. (These ratios are calculated simply as the total annualized costs divided by the tons abated for each alternative. Other ratios based on incremental costs from the baseline cost and incremental abatement from the baseline abatement level could also be calculated to provide similar relationships.)

Two other alternatives, E and F, are also shown in Figure 4. No conclusive choice can be made among Alternatives D, E and F using on1y C/E analysis. The following data will illustrate this.

Alternative	Annualized cost $million	Emissions abated (1,000 tons)
D	71.3	183.2
E	41.0	172.5
F	134.0	190.0

Alternative E is less effective than D, but E costs less. Analysts must know whether the marginal benefits of achieving the greater effectiveness of D exceed its marginal costs. Similarly, Alternative F costs more than D and is also more effective; hence, analysts must again consider the benefits as well as the costs to determine the preferred alternative. Each of these three alternatives maintains its dominance over the others because it either costs less or it is more effective. None can be said to be inferior to the others and, thus, each alternative is a member of the least-cost C/E set. Calculating C/E ratios for this set of alternatives in the manner used for A, B, C, and D, above, will not provide a basis for choosing one alternative over another because, although the C/E ratios will increase as the abatement level increases, the associated benefits may also.

Provided that a thorough C/E analysis is performed and that benefit-cost analyses are made for each least-cost alternative, the choice among the D, E, and F alternatives can be made on the basis of each‘s maximum contribution to net social benefits (theoretically, this occurs at the point where marginal social benefits equal marginal social costs):

$$NSB = TSB - TSC$$

where

NSB = Net Social Benefit
TSB = Total Social Benefit
TSC = Total Social Cost

(TSB and TSC are the values generated (in present value terms) in sections B and C, respectively.)

Presuming that similar analyses have been made for Alternatives E and F as well as D, the following hypothetical comparison could be made:

	Present value ($million)		
Alternative	TSB	TSC	NSB
D	444.6	360.9	83.7
E	300.0	230.0	70.0
F	640.0	620.0	20.0

In this illustration, Alternative D contributes $83.7 million to NSB whereas either E or F contributes less. Even though Alternative F has substantially more benefits than D, the net gain (above TSC) to society is less. Because these alternatives and the implicit data are discrete, one could not know if an intermediate point (alternative) between E and D or between D and F would yield a higher NSB than Alternative D.

As might be readily envisioned, the definition and delineation of regulatory alternatives for cost-effectiveness analysis can be and generally are major tasks. Costs and abatement effects are not always readily defined, particularly for multipollutant control problems where joint costs and interrelationships among pollution generation rates exist. Also, although aggregate industry results were depicted above, each industry (and important industry segments) should be considered separately.

In summary, C/E analysis is an important and rigorous analytical technique for pre-selecting regulatory alternatives and for reducing the number of alternatives which will require further analysis, e.g., benefit-cost analysis. The subset of cost-effective alternatives that are said to form the least-cost envelope curve will constitute those alternatives requiring such additional analysis.